Cruise of the *FRV W. E. RICKER*, November 2-13, 1987 to Hecate Strait to Study Reproductive Biology of Pacific Cod and English Sole

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CRUISE OF THE FRV W. E. RICKER, NOVEMBER 2-13, 1987 TO HECATE STRAIT TO STUDY REPRODUCTIVE BIOLOGY OF PACIFIC COD AND ENGLISH SOLE

by

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ABSTRACT

Tyler, A. V., J. Fargo, and R. P. Foucher. 1988. Cruise of the FRV W. E. RICKER, November 2-13, 1987 to Hecate Strait to study reproductive biology of Pacific cod and English sole. Can. MS Rep. Fish. Aquat. Sci. 1979: 72 p.

Ovaries were obtained from Pacific cod and English sole from three grounds in Hecate Strait for histological examination of the ovarian cycle. Length at 50% maturity was estimated at 47 cm for Pacific cod for Horseshoe, 46 cm at White Rocks/Bonilla, and 54 cm at Two Peaks/Butterworth. For English sole, length at 50% maturity was estimated at 31 cm for Horseshoe, 33 cm for White Rocks/Bonilla, and 37 cm for Two Peaks/Butterworth. Ovary weight vs fish weight and liver weight vs fish weight relationships were fitted and graphed for both species. English sole were also sampled for fecundity from Horseshoe. Ageing structures (otoliths) were taken from English sole with the fecundity sample. The overall length frequency of Pacific cod suggests a weak 1984 year-class, a relatively strong 1985 year-class, and an intermediate 1986 year-class. Water temperatures during the cruise were warm--8.0 to 8.2°C on bottom.

RÉSUMÉ

Tyler, A. V., J. Fargo, and R. P. Foucher. 1988. Cruise of the FRV W. E. RICKER, November 2-13, 1987 to Hecate Strait to study reproductive biology of Pacific cod and English sole. Can. MS Rep. Fish. Aquat. Sci. 1979: 72 p.

On a prélevé les ovaires de morues du Pacifique et de soles anglaises capturées dans trois pêcheries du détroit d'Hécate en vue d'une étude histologique des différents stades du cycle ovarien. Dans le cas de la morue du Pacifique, on a déterminé que la longueur à la maturité chez 50% des individus se situait à 47 cm sur le banc Horseshoe, à 46 cm sur les bancs White Rocks/Bonilla et à 54 cm sur les bancs Two Peaks/Butterworth. Pour ce qui est de la sole anglaise, cette longueur atteignait 31 cm, 33 cm et 37 cm respectivement pour les mêmes pêcheries. Les relations poids des ovaires v. poids du poisson et poids du foie v. poids du poisson ont été ajustées et portées sur un graphique dans le cas des deux espèces. On a aussi effectué un échantillonnage de la sole anglaise du banc Horseshoe afin de déterminer son taux de fécondité et son âge (otolithes). La fréquence globale des longueurs de la morue du Pacifique porte à croire que la classe annuelle de 1984 est faible, que celle de 1985 est relativement importante et que celle de 1986 occupe une position intermédiaire. Au cours de l'expédition, la température de l'eau était chaude, soid de 8,0 à 8.2°C au fond.

INTRODUCTION

This report summarizes results of the third cruise in a series to investigate the reproductive biology of Pacific cod and English sole in Hecate Strait. (Foucher et al. 1987, Tyler et al. 1987). In addition, observers went on commercial trips in March and August and took samples for the reproductive biology study. Also, samples were taken on the June 1987 assemblage survey in Hecate Strait. Reports are in preparation for these trips. The biological relationships under study include fecundity as a function of body weight and age, size at 50% maturity, spawning timing, and the progression of oocyte development by means of histological tissue preparation.

MATERIALS AND METHODS

The grounds fished were Horseshoe, White Rocks/Bonilla and Two Peaks/Butterworth (Fig. 1). The White Rocks/Bonilla area was also fished in the first cruise of the series (Tyler et al. 1987) which was cut short because of a winch failure. White Rocks/Bonilla and Two Peaks/Butterworth were fished on other trips during 1987. Three areas, significantly far apart, were desired so that a test for homogeneity in the data with regard to latitude could be made. Positions for trawl hauls were selected at the discretion of the vessel skipper from records of previous research cruises.

The vessel employed was the FRV W.E. RICKER, fishing a 145 Engel trawl with a 96-ft headrope and a 145-ft footrope. The net was fished with the ship's 1-tonne, oval, steel doors used with 50-meter sweeps. The warp consisted of 1 1/8-inch, steel cable. The net mesh sizes were: 7-inch in the wings, 6-inch in the square, 5-inch in the belly and 3-inch in the codend. There were steel floats on the headline and the groundline had 14-inch, rubber bobbins in the bosom section, and 6-inch, rubber disks in the wing sections (Fig. 2).

The entire catch was dumped into the fish hopper leading to the fish-handling laboratory below deck. All Pacific cod and English sole were sorted from the conveyer belt into plastic baskets. All fish set aside were measured for fork length to the nearest cm. English sole and Pacific cod were classified as males, immature females, or mature females.

Length, sex, and maturity data were recorded, and selected, individual fish were weighed (with stomachs emptied), and their ovaries removed and weighed. In the case of Pacific cod, both ovaries were removed, while for English sole only the right ovary was removed. Ovaries were preserved in buffered formal saline for later histological preparation. The sampling schedule used for the cruise is listed in Table 1.

A length-stratification procedure was used to ensure that samples were spread throughout the anticipated length range of each species. Sampling and weighing were carried out in a protected anchorage after fishing was completed each day.

Buffered formal saline was made up (for 20 l of solution) as follows:

2 l formalin	80 g NaH_2PO_4
18 l water	130 g Na_2HPO_4
	180 g NaCl

Both otoliths were removed from each English sole and stored in glycerine/thymol for later age determination.

Temperature profiles were taken using expendable bathythermographs for each fishing ground and usually on each day of fishing.

Percent maturity at length was plotted for each of the three grounds and for all three combined. Length at 50% maturity was determined by two methods. The first method was by linear regression weighted by the number of fish sampled at each length and including only those lengths for which percent mature was between 10 and 90. The second method was a maximum likelihood method using equation 5 of Welch and Foucher (1988) to estimate parameters from which lengths at 50% maturity were calculated using equation 6. This method also weights points by the number sampled but, in addition, includes all the data.

RESULTS

Thirteen trawl sets were made on November 4 through November 12; 6 at Horseshoe, 3 at White Rocks/Bonilla, and 4 at Two Peaks/Butterworth. Figure 1 shows the positions of the hauls. Bridge-log information is given in Appendix Table 1.

A total of 1585 Pacific cod and 3485 English sole were measured. Length-frequency data for Pacific cod included 213 immature females, 598 mature females and 774 males. For English sole, the data included 1697 males, 683 immature females, 984 mature females and 121 females measured without reference to maturity. Tables 2 and 3 summarize by sex, maturity, ground and haul the length frequency sampling completed for Pacific cod and English sole respectively. Tables 4 and 5 summarize, by size range and ground, the sampling completed for other sample types for Pacific cod and English sole respectively. Table 6 shows temperature data taken in conjunction with five of the hauls.

LENGTH FREQUENCY AND SIZE-AT-MATURITY FOR PACIFIC COD

Pacific cod length frequencies are summarized for Horseshoe, White Rocks/Bonilla, Two Peaks/Butterworth and all grounds combined in Figures 3-6, respectively (see also Appendix Table 2). Figures 3-6 each show immature, mature, all females and all the males. The length composition is quite similar between grounds. The dominant length mode corresponds to the 1985 year-class.

Age-0^+ fish (1987 year-class) were taken on the Horseshoe Ground with a modal-length of 23-24 cm (Fig. 3). In the 30 to 40 cm range there were more small males at the Horseshoe than at either White Rocks/Bonilla, or Two Peaks/Butterworth. The smaller mature females were found to the south at the Horseshoe, and White Rocks/Bonilla. On the other hand there were proportionately more large immature females (45-55 cm range) at Two Peaks/Butterworth and White Rocks/Bonilla than at the Horseshoe to the south. These observations are all consistent with the possibility that the fish to the south represented a pre-spawning concentration.

The lengths at 50% maturity as determined by the two methods were:

	Horseshoe	White Rocks/ Bonilla	Two Peaks/ Butterworth	All grounds
Linear regression	46.9	46.2	54.9	48.1
Maximum likelihood	48.0	47.2	54.8	48.5

Though the Two Peaks/Butterworth estimate is not well determined due to the small sample size (N = 81), the apparent larger size for first maturity is consistent with earlier findings (Welch and Foucher 1988). These findings suggest that either maturation occurs at a smaller size to the south, or that, as young fish mature, there is a partial translocation southward prior to spawning, leaving larger immature fish in the north, and causing more of the smaller mature fish to be in the south.

Maturation appeared to be inhibited in 3 fish from White Rocks/Bonilla. These fish (lengths 54, 68 and 69 cm) were immature and had parabranchial lesions.

HISTOLOGICAL AND FECUNDITY SAMPLES, OVARY AND LIVER WEIGHTS FOR PACIFIC COD

Ovaries were preserved from 54 immature fish and 110 mature fish from the combination of localities for histological studies. Sample sizes by location are given in Table 2. Ovary weight appears to increase in a linear manner with increase in body weight (Fig. 11, 12, 13). Immature fish and mature fish appear to have separate relationships. The scatter of ovary

weights seems greater at higher body weights at Horseshoe and Two Peaks/Butterworth grounds (Figs. 11, 13). In general, the ovary weight to body weight relationship is similar among the three grounds.

Liver weight increased linearly with body weight (Fig. 14). Twenty-five mature fish and 1 immature fish were sampled at Two Peaks/Butterworth.

SEX RATIOS FOR PACIFIC COD

The overall sex ratio, males:females was 0.95, for all localities combined. There were fewer males than females at White Rocks/Bonilla (males:females = 514:562 = 0.92). At the other localities there were about equal numbers: Horseshoe, males:females = 174:167 = 1.04; Two Peaks/Butterworth, 86:82 = 1.05.

LENGTH FREQUENCY AND SIZE-AT-MATURITY DATA FOR ENGLISH SOLE

Length-frequency data were recorded for 1697 males, 683 immature females, 984 mature females, and 121 females whose maturity state was not determined (Appendix Table 3). Length-frequency histograms were similar at all localities (Figs. 15, 16, 17). The males showed a mode between 27 and 34 cm. The females showed two modes, a mode for immature fish in the 20-25 cm range, and a mode of mixed matures and immatures in the 30-40 cm range (Fig. 18).

The lengths at 50% maturity as determined by the two methods were:

	Horseshoe	White Rocks/ Bonilla	Two Peaks/ Butterworth	All grounds
Linear regression	31.1	33.0	36.7	33.1
Maximum likelihood	31.2	32.8	35.1	33.1

The smallest mature fish were 25 cm, and the largest immature individuals were 44 cm. More of the smallest, mature fish occurred on the Horseshoe Ground.

HISTOLOGICAL AND FECUNDITY SAMPLES, OVARY AND LIVER WEIGHTS FOR ENGLISH SOLE

Ovaries were preserved from 76 immature fish and 118 mature fish from all localities for histological studies. In addition, ovaries and otoliths were taken from 71 mature females for fecundity studies from Horseshoe Ground, and livers were preserved from 25 immature fish and 25 mature fish from White Rocks/Bonilla Ground.

Ovaries of immature fish could not be weighed because of their small size, and the motion of the vessel even at anchor in a protected bay. Ovary and body weights of all mature fish were measured. There was no significant correlation between ovary weight and body weight at Horseshoe Ground (Fig. 23). The degree of scatter of ovary weight for a specific fish weight was due to the combined presence of fish that had recently spawned and those that were apparently ready to spawn. Oocytes were loose in the ovaries of some fish, indicating that spawning was in progress at time of capture. There was a significant correlation between ovary weight and body weight in the White Rocks/Bonilla sample (Fig. 24), but farther north at Two Peaks/Butterworth the variance increased again and there was no significant correlation (Fig. 25). The fish at 900 g at Two Peaks/Butterworth, and 1100 g at White Rocks/Bonilla were well out of the range of the other fish and were not included in the regressions. The increased variance in the Two Peaks/Butterworth sample cannot be explained at this time, but after the histological analysis is complete the variance in weight might be explainable by stage of maturation. The similar plots for the White Rocks/Bonilla and Two Peaks/Butterworth samples indicate similar ovary weight at body weight for the two localities.

The liver weights and body weights for 25 immature and 25 mature fish show a continuous relationship between immature and mature stages, and a significant correlation (Fig. 26).

SEX RATIOS FOR ENGLISH SOLE

The over-all sex ratio, for males to females, was 0.949, giving the expected total population ratio of half males and half females. However, there were more males than females at Horseshoe and White Rocks/Bonilla, where there were spawning females. (males:females = 1.18). Conversely, there were more females at Two Peaks/Butterworth (males:females = 0.32).

SECONDARY OBJECTIVES

Testes were frozen from 30 English sole with accompanying length, date, locality data. This sample is being sent to Dr. Garth Fletcher, Memorial University of Newfoundland for genetic studies.

Two specimens of all species encountered were frozen for Mr. R. Stanley to provide training material for Mr. C. Chestnut of Malaspina College.

ACKNOWLEDGMENTS

We thank Mr. Jim Cooper for his technical help during a portion of the cruise. The Captain of the vessel, A. Ranger, the officers, and the crew were a pleasure to work with, and were instrumental to the smooth manner in which the cruise was carried out.

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Table 1. Sampling schedule for English sole and Pacific cod (both females only) for FRV W. E. RICKER cruise to Hecate Strait, November 2-13, 1987.

Species	Sample type	Maturity state	Size range(cm)	No. per interval	Interval size(cm)	Total no.[a]
Pacific cod	Fecundity[b]	Mature	40 - 90	10	5	100
	Histology	Immature	10 - 50	5	10	20
	"	Mature	40 - 90	8	5	80
	Maturity ogive	Mat/Imm	any size	up to total[c] of		1000
	Livers	Mature	any size			25
	"	Immature	any size			25
English sole	Fecundity	Mature	25 - 50	10	2	125
	Histology	Immature	10 - 35	5	5	25
	"	Mature	25 - 50	15	5	75
	Livers	Mature	any size			25
	"	Immature	any size			25
	Testes	Mature	any size			30

[a]Numbers to be sampled for fecundity and histology apply to each of three sampling areas.

[b]Pacific cod fecundity sample not expected--spawning is mainly February-March.

[c]Total including fish sampled for fecundity and histology.

Table 2. Number of Pacific cod sampled by sex and maturity, ground and haul during the cruise of the FRV W. E. RICKER to Hecate Strait, November 2-13, 1987.

Ground	Haul no.	Sex/Maturity			Total by ground
		Male	Female		
			Imm.	Mat.	
Horseshoe	1	32	17	0	
	2	37	29	0	
	3	55	4	50	
	4	24	8	24	
	5	22	7	26	
	6	4	2	0	
	Total	174	67	100	341
Two Peaks/ Butterworth	9	37	28	8	
	10	15	10	6	
	11	24	8	12	
	12	10	3	7	
	Total	86	49	33	168
White Rocks/ Bonilla	7	15	5	11	
	8	2	1	3	
	13	497	193	449	
	Total	514	99	463	1076
Combined grounds/hauls		774	215	596	1585

Table 3. Number of English sole sampled by sex and maturity, ground and haul during the cruise of the FRV W. E. RICKER to Hecate Strait, November 2-13, 1987.

Ground	Haul no.	Sex/Maturity				Total by ground
		Male	Female			
			Imm.	Mat.	Unk.	
Horseshoe	1	216	0	0	121	
	2	288	101	310	-	
	3	0	0	0	-	
	4	89	24	61	-	
	5	95	18	19	-	
	6	204	36	65	-	
	Total	892	179	455	121	1647
Two Peaks/	9	1	20	21	-	
Butterworth	10	25	138	83	-	
	11	83	86	60	-	
	12	46	58	18	-	
	Total	155	302	182	-	639
White Rocks/	7	276	105	210	-	
Bonilla	8	44	7	29	-	
	13	330	90	108	-	
	Total	650	202	347	-	1199
Combined gounds/hauls		1697	683	984	121	3485

Table 4. Summary of samples taken for Pacific cod during the cruise of the FRV W. E. RICKER to Hecate Strait, November 2-13, 1987.

Sample type	Maturity state	Size range(cm)	Number required per area	Number sampled by area		
				HS	WR/BO	TP/BU
Histology	Immature	10-19	5	0	0	0
		20-29	5	0	0	0
		30-39	5	8	1	1
		40-49	5	7	5	6
		50-59	5	7	6	9
		60-69	5	1	2	1
		Total		23	14	17
	Mature	40-44	8	0	2	0
		45-59	8	2	8	4
		50-54	8	3	8	7
		55-59	8	10	8	14
		60-64	8	9	8	2
		65-69	8	3	7	5
		70-74	8	1	5	2
		75-79	8	0	1	0
		80-84	8	1	0	0
		Total		29	47	34
	Immature + mature	Total		52	61	51
Livers	Immature	any size/area	25			1
	Mature	any size/area	25			26

Table 5. Summary of samples taken for English sole during the cruise of the FRV W. E. RICKER to Hecate Strait, November 2-13, 1987.

Sample type	Maturity state	Size range(cm)	Number required per area	Number sampled by area		
				HS	WR/BO	TP/BU
Fecundity	Mature	25-26	10	3		
		27-28	10	2		
		29-30	10	4		
		31-32	10	10		
		33-34	10	11		
		35-36	10	11		
		37-38	10	11		
		39-40	10	8		
		41-42	10	5		
		43-44	10	5		
		45-46	10	0		
		47-48	10	1		
		49-50	10	0		
		Total		71		
Histology	Immature	10-14	5	0	0	0
		15-19	5	1	0	0
		20-24	5	6	10	7
		25-29	5	5	5	4
		30-34	5	6	11	5
		35-39	5	0	5	5
		40-44		0	0	0
		45-49		0	1	0
		Total		18	32	21
	Mature	25-29	15	0	0	0
		30-34	15	15	4	7
		35-39	15	16	15	13
		40-44	15	13	15	15
		45-49	15	0	3	6
		50-54	15	0	0	1
				44	37	42
Livers	Immature	any size	25		25	
	Mature	any size	25		25	
Testes	Mature	any size	30	30		

Table 6. Location of hydrographic station and water temperatures (°C) at standard depths (m) during the cruise of the FRV W. E. RICKER to Hecate Strait, November 2-13, 1987.

Haul no.	Date	Time (PST)	N. lat. ° '	W. long. ° '	Standard depths (m) 0	10	20	30	50	75	100	Bottom °C	Bottom Depth (m)	Bucket temperature On (°C)
1	4	1000	52 59.4	130 43.9	10.5	10.5	10.5	10.5	9.8	9.3	8.2	8.2	100	-
4	5	0910	52 59.9	130 41.9	10.3	10.3	10.5	10.5	10.5	9.3	8.1	8.0	119	10.3
7	6	0945	53 45.0	130 48.5	10.0	9.8	10.3	10.2	10.3	10.0	9.2	8.2	112	9.7
10	10	2242	54 21.1	131 14.2	-[a]	9.7	9.6	9.6	8.3	8.0	-	8.0	87	9.9
11	11	1850	54 03.4	131 03.3	-[a]	10.1	10.1	10.4	11.1	11.4	-	11.7	90	10.1

[a]XBT surface temperature considered unreliable.

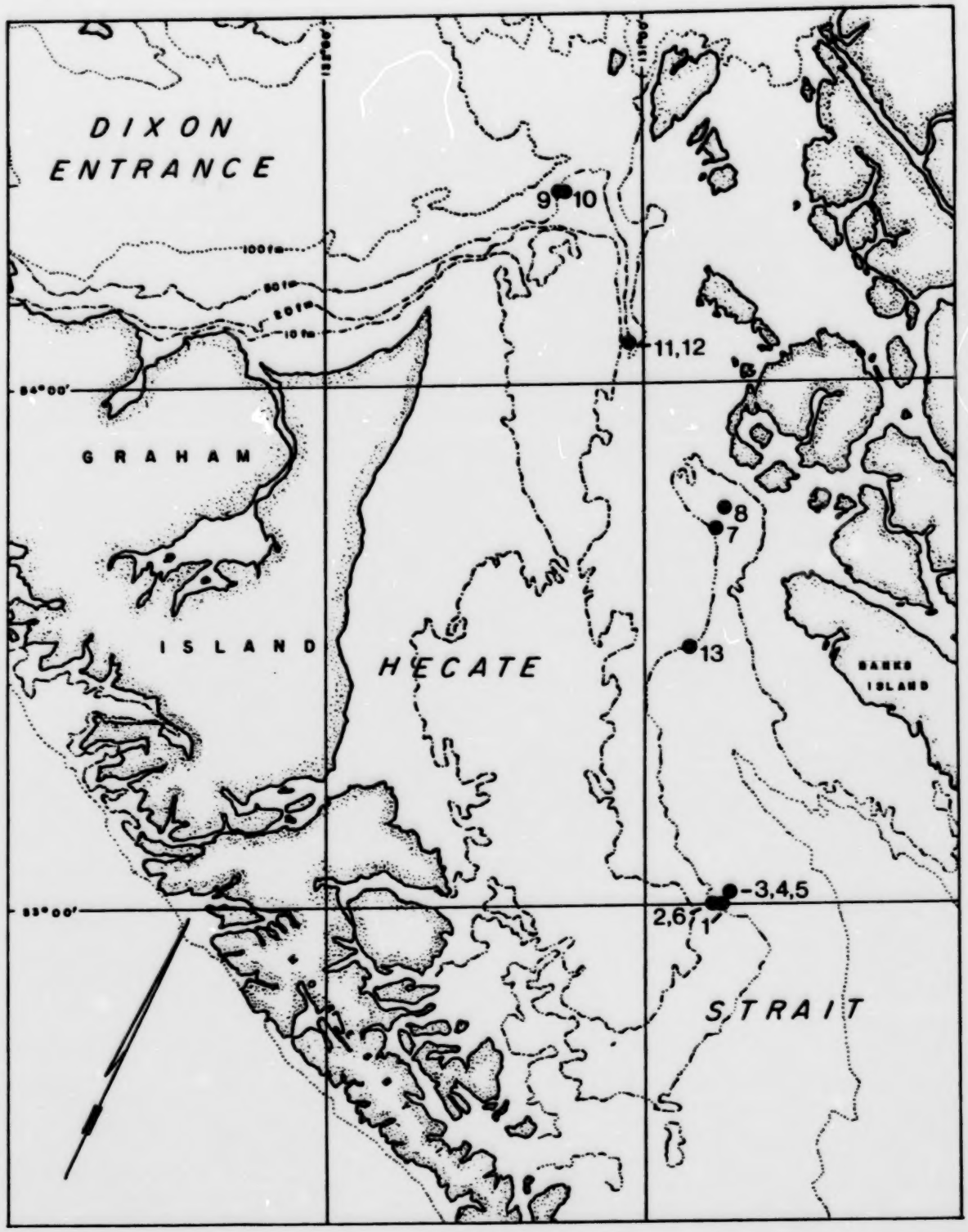


Fig. 1. Areas fished and positions of the trawl sets.

NET DIMENSIONS AND CHARACTERISTICS FOR BOTTOM TRAWL

VESSEL FR/V W.E. RICKER NET Engel 145

OBSERVATION PERIOD Nov. 2-13, 1987

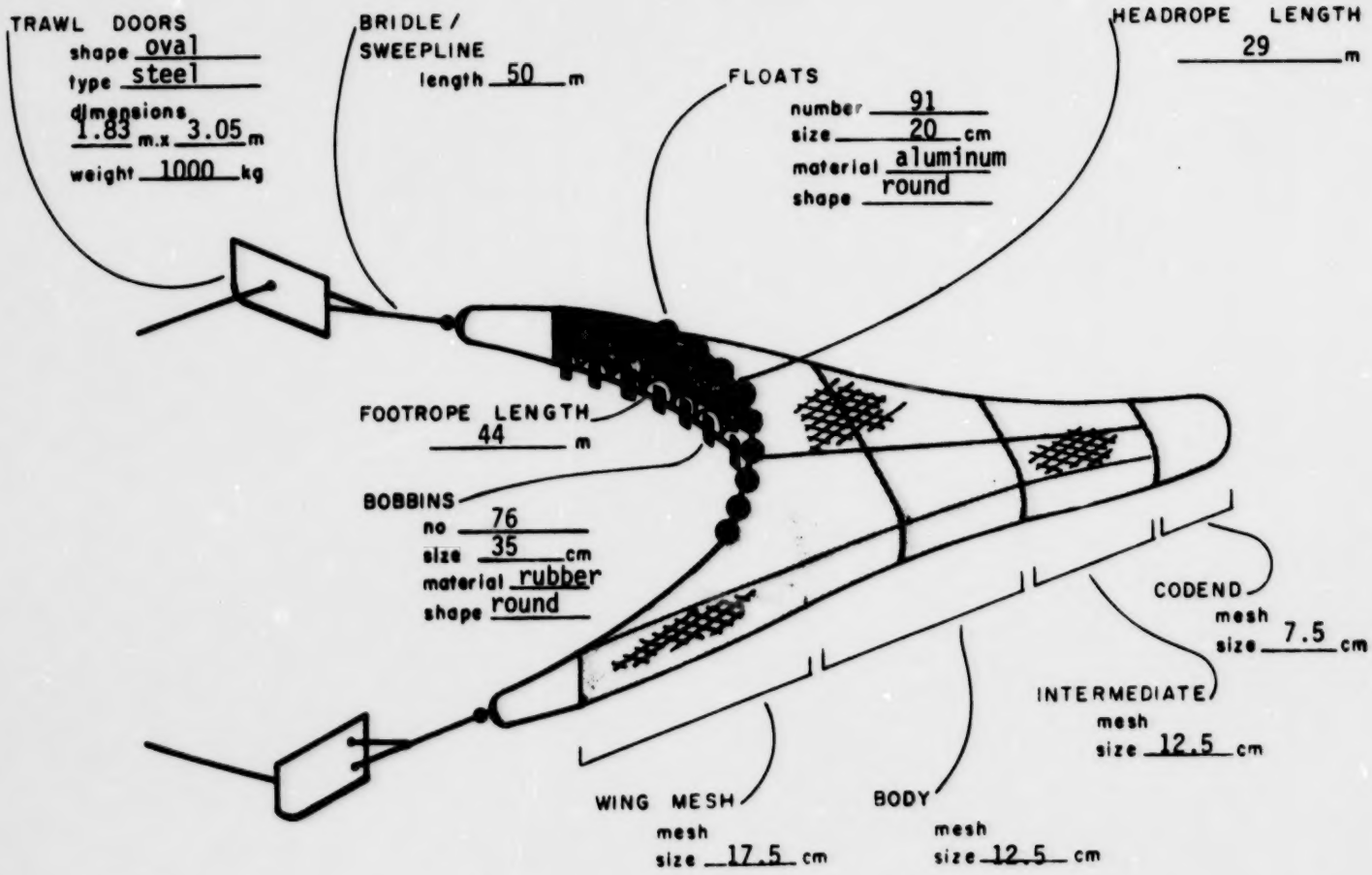


Fig. 2. Net dimensions and characteristics for the bottom trawl.

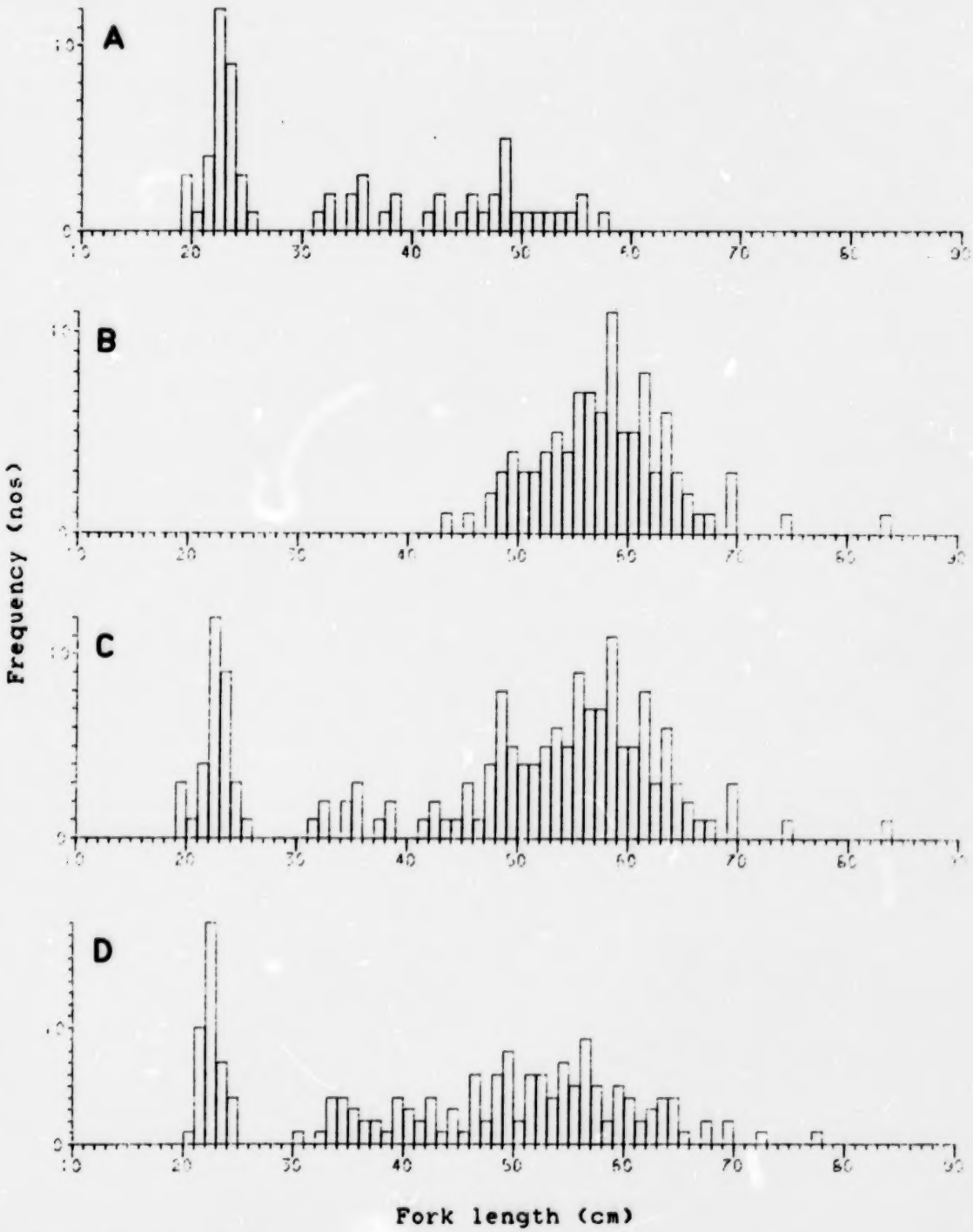


Fig. 3. Length frequency of Pacific cod from Horseshoe Ground A) female immature, N=67; B) female mature, N=100; C) all females, N=167; D) males, N=174.

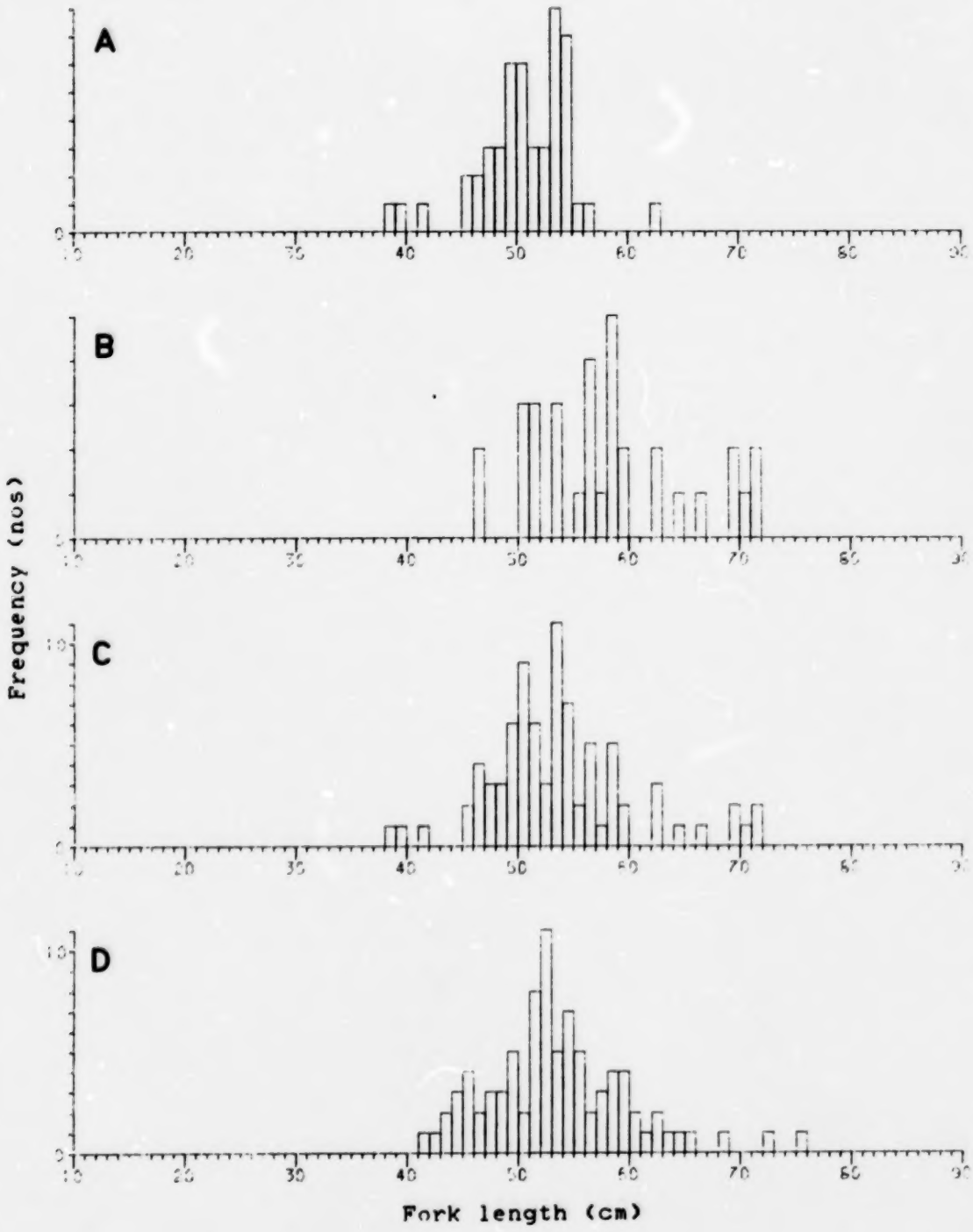


Fig. 4. Length frequency of Pacific cod from Two Peaks-Butterworth Ground A) female immature, N=49; B) female mature, N=33; C) all females, N=82; D) males, N=86.

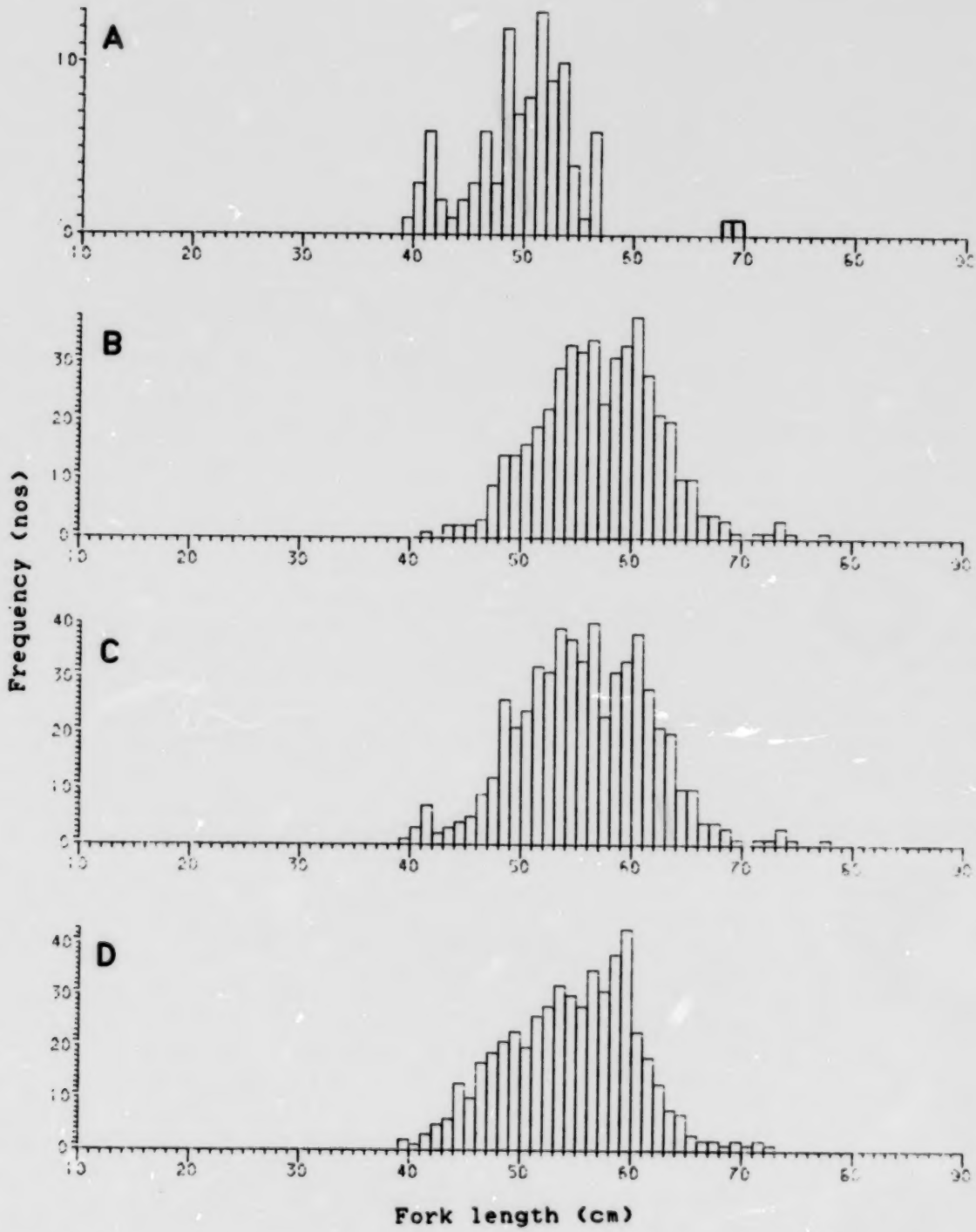


Fig. 5. Length frequency of Pacific cod from White Rocks-Bonilla Ground A) female immature, N=99; B) female mature, N=463; C) all females, N=562; D) males, N=514.

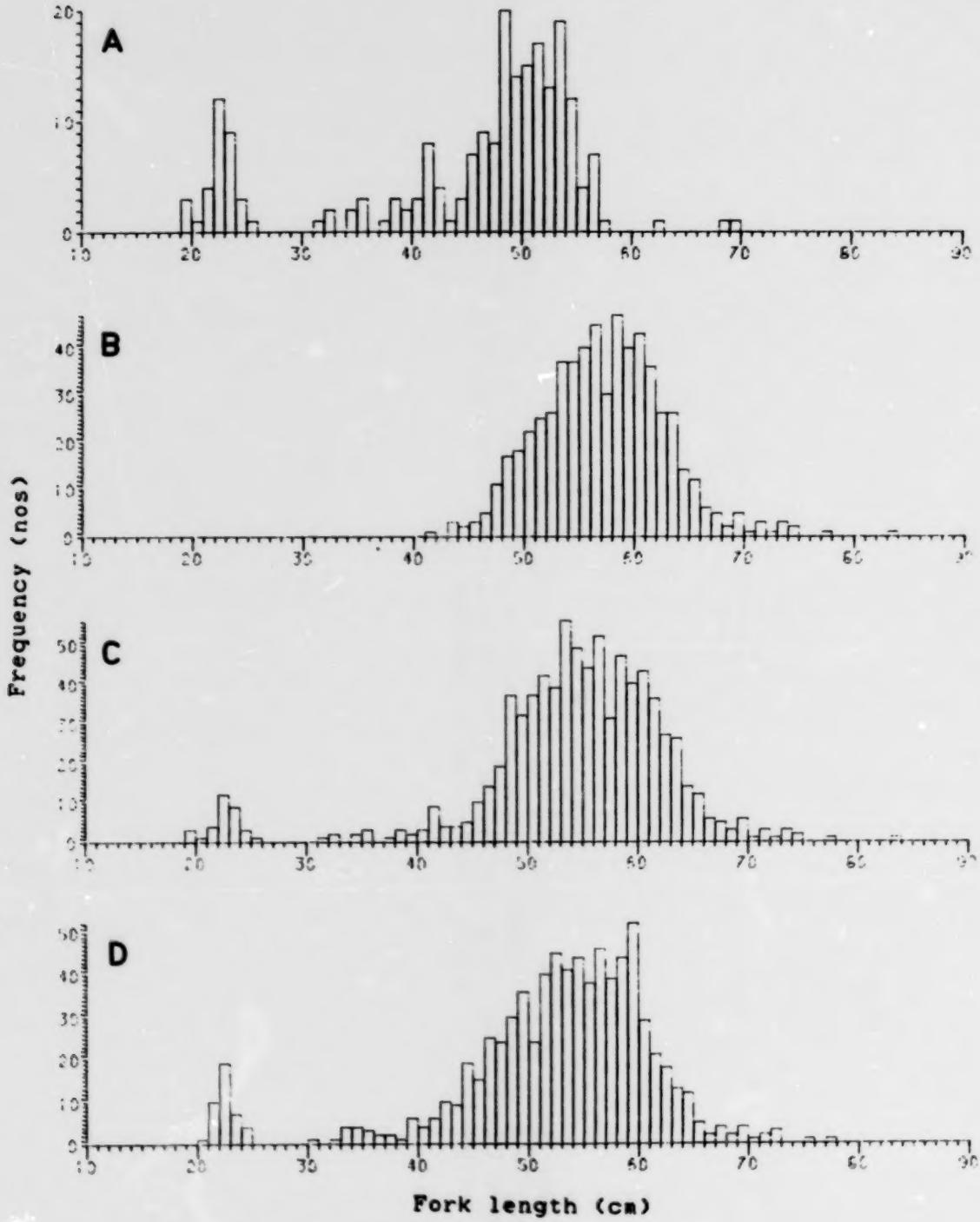


Fig. 6. Length frequency of Pacific cod from all grounds combined A) female immature, N=215; B) female mature, N=596; C) all females, N=811; D) males, N=774.

Fig. 7. Percentage mature vs. length for Pacific cod, all areas combined. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=4.16X-150$; $r^2 = 0.846$. Numbers sampled indicated.)

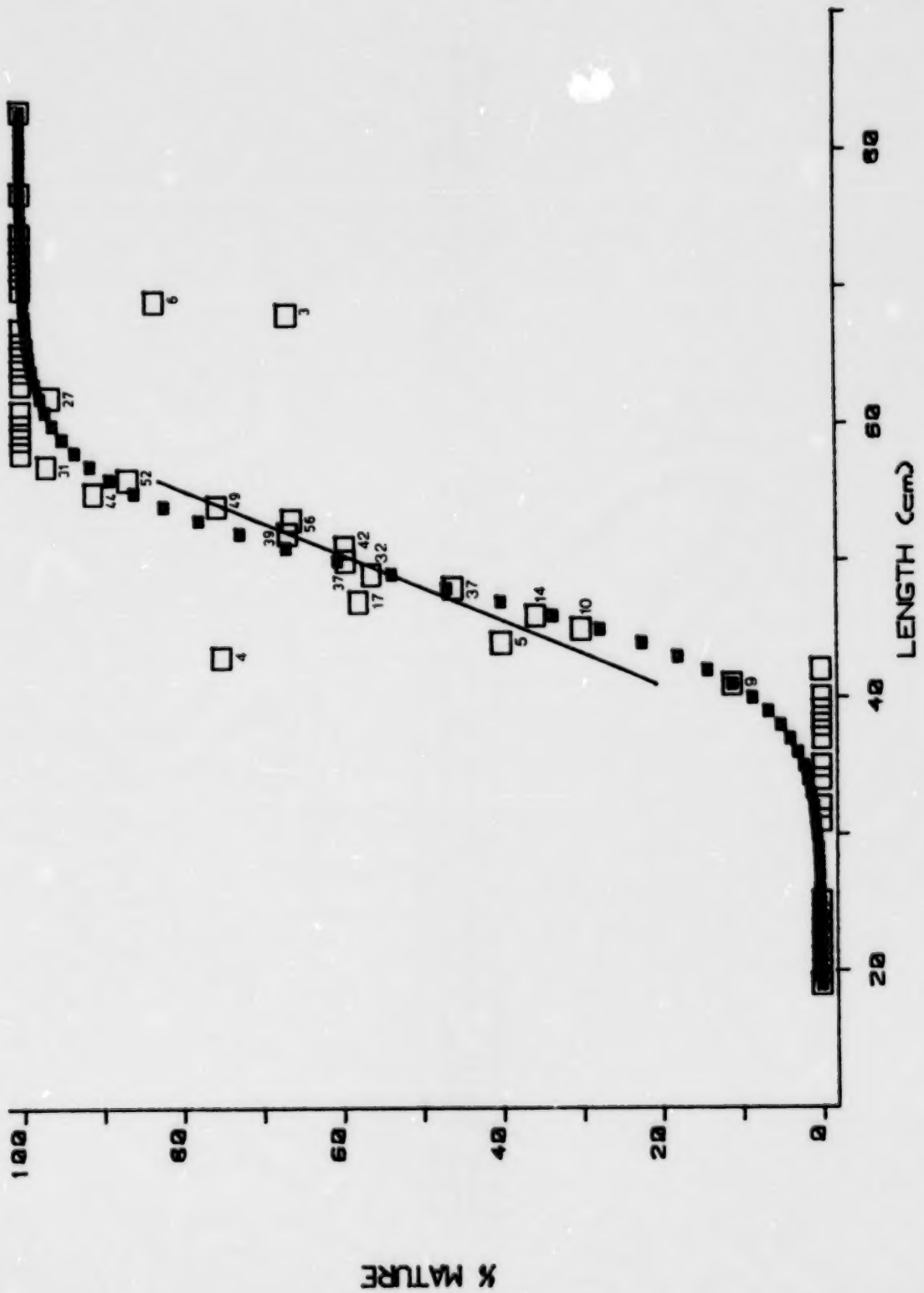

% MATURE
100
80
60
40
20
0
20
40
60
80
LENGTH (cm)
6
3
27
31
44
52
49
39
56
37
42
32
17
37
4
5
14
10
9

Fig. 8. Percentage mature vs. length for Pacific cod, Horseshoe Ground. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=4.48X-160$; $r^2 = 0.656$. Numbers sampled indicated.)

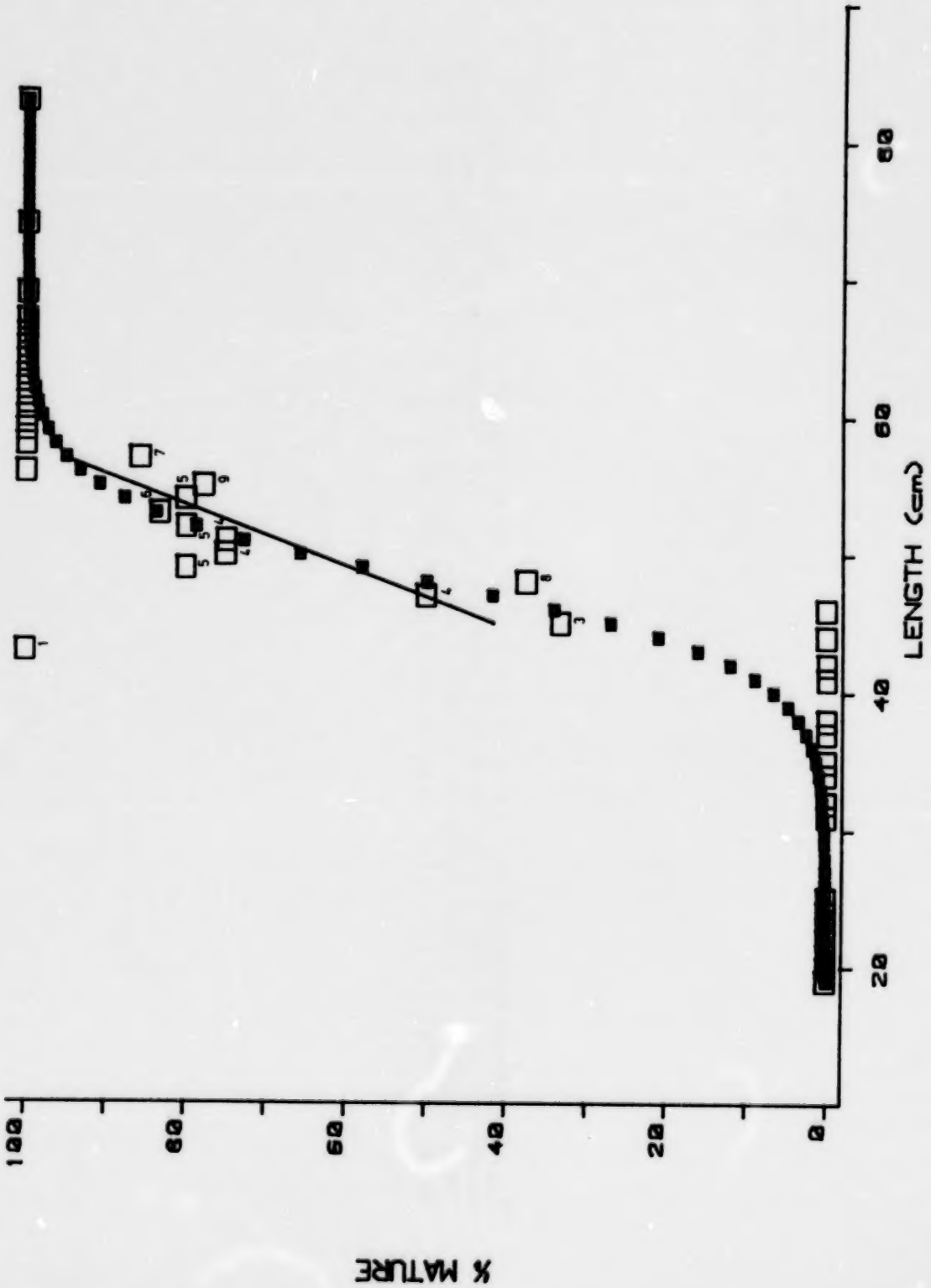

% MATURE
100
80
60
40
20
0
20
40
60
80
LENGTH (cm)

Fig. 9. Percentage mature vs. length for Pacific cod, White Rocks/Bonilla. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=3.90X-130$; $r^2 = 0.723$. Numbers sampled indicated.)

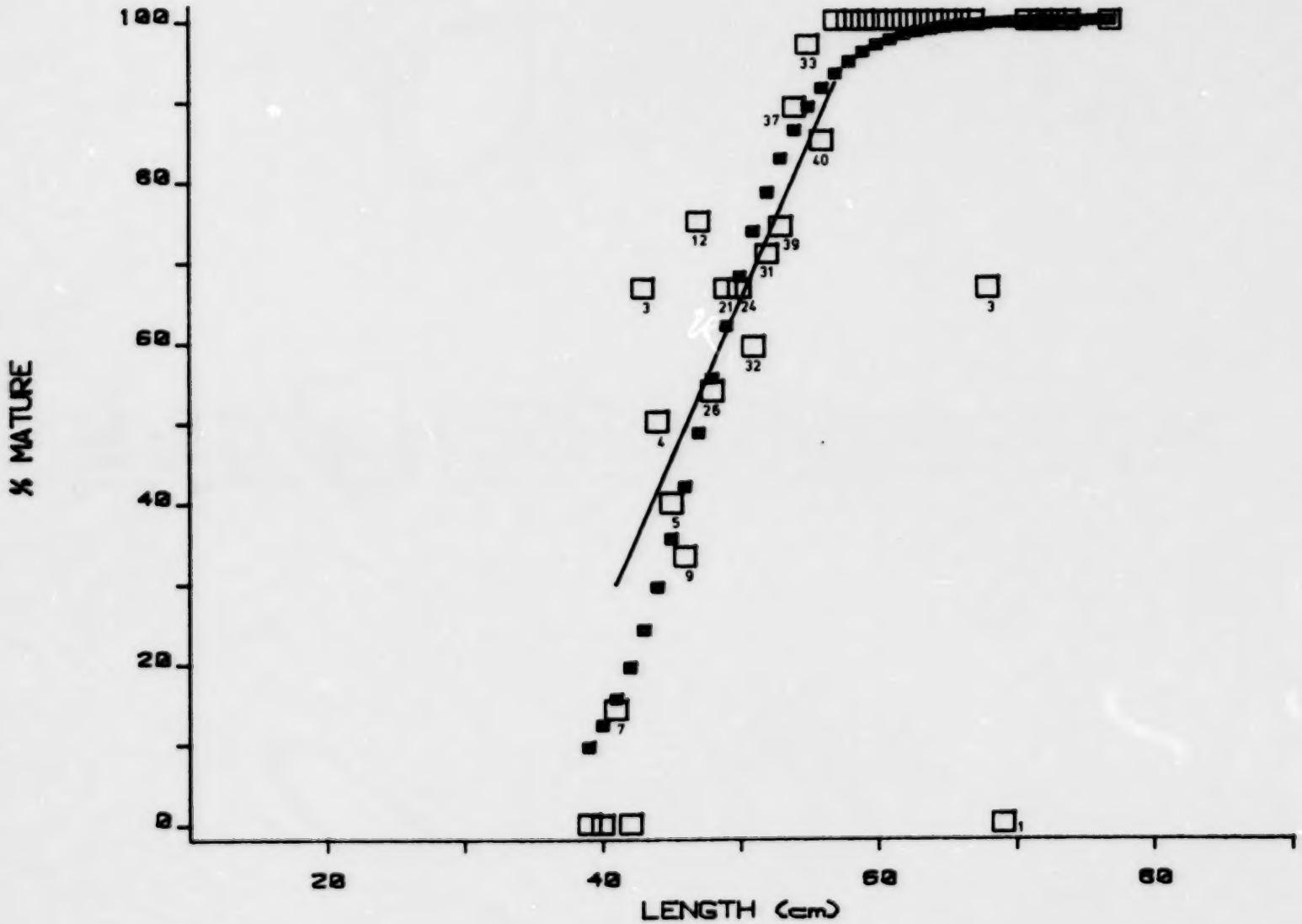
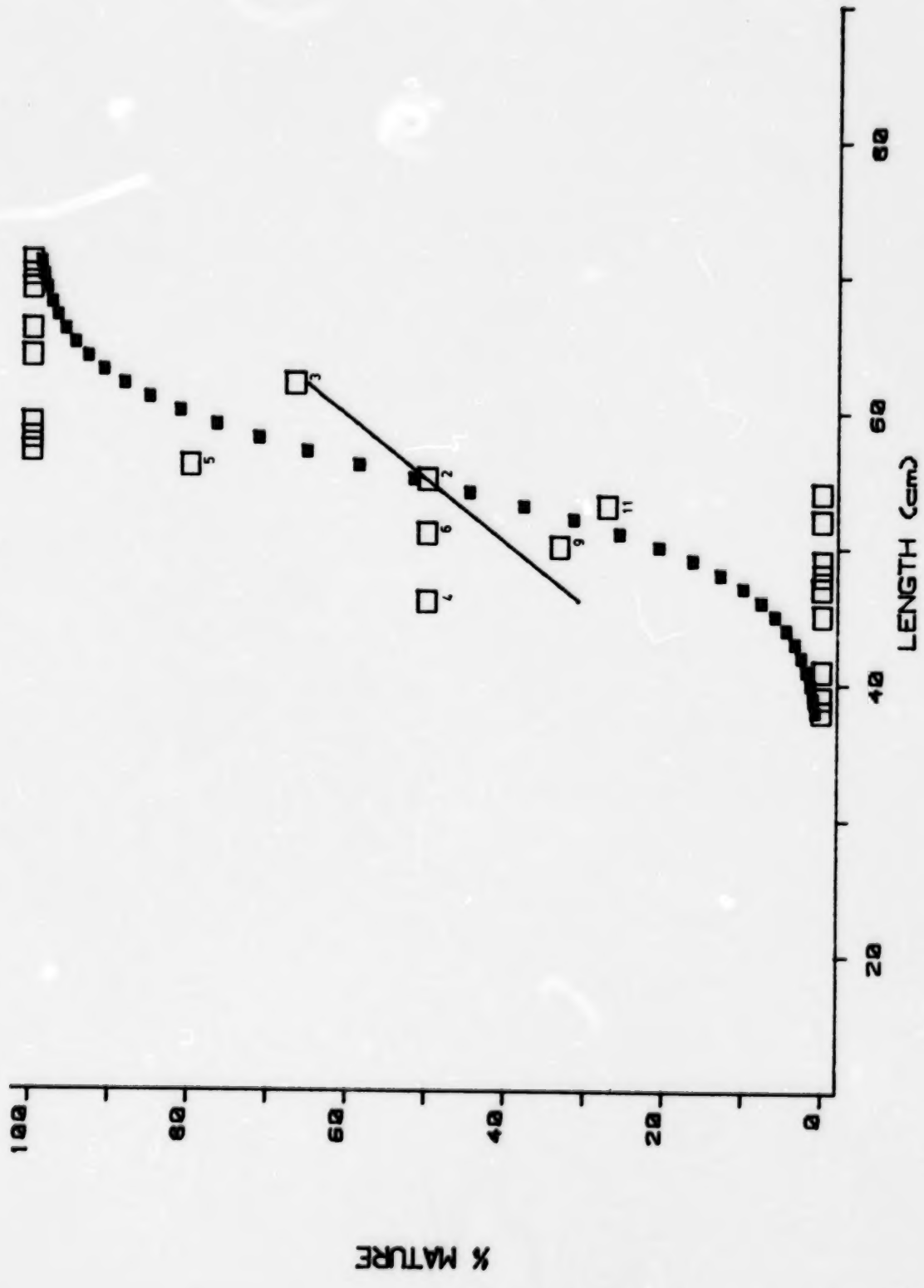

100
80
60
40
20
0
% MATURE
20
40
60
80
LENGTH (cm)
33
37
40
12
39
31
3
21
24
3
32
26
4
5
9
7
1

Fig. 10. Percentage mature vs. length for Pacific cod, Two Peaks/Butterworth. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=2.15X-68.0$; $r^2 = 0.212$. Numbers sampled indicated.)


% MATURE
100
80
60
40
20
0
20
40
60
80
LENGTH (cm)
3
5
2
6
7
9
11

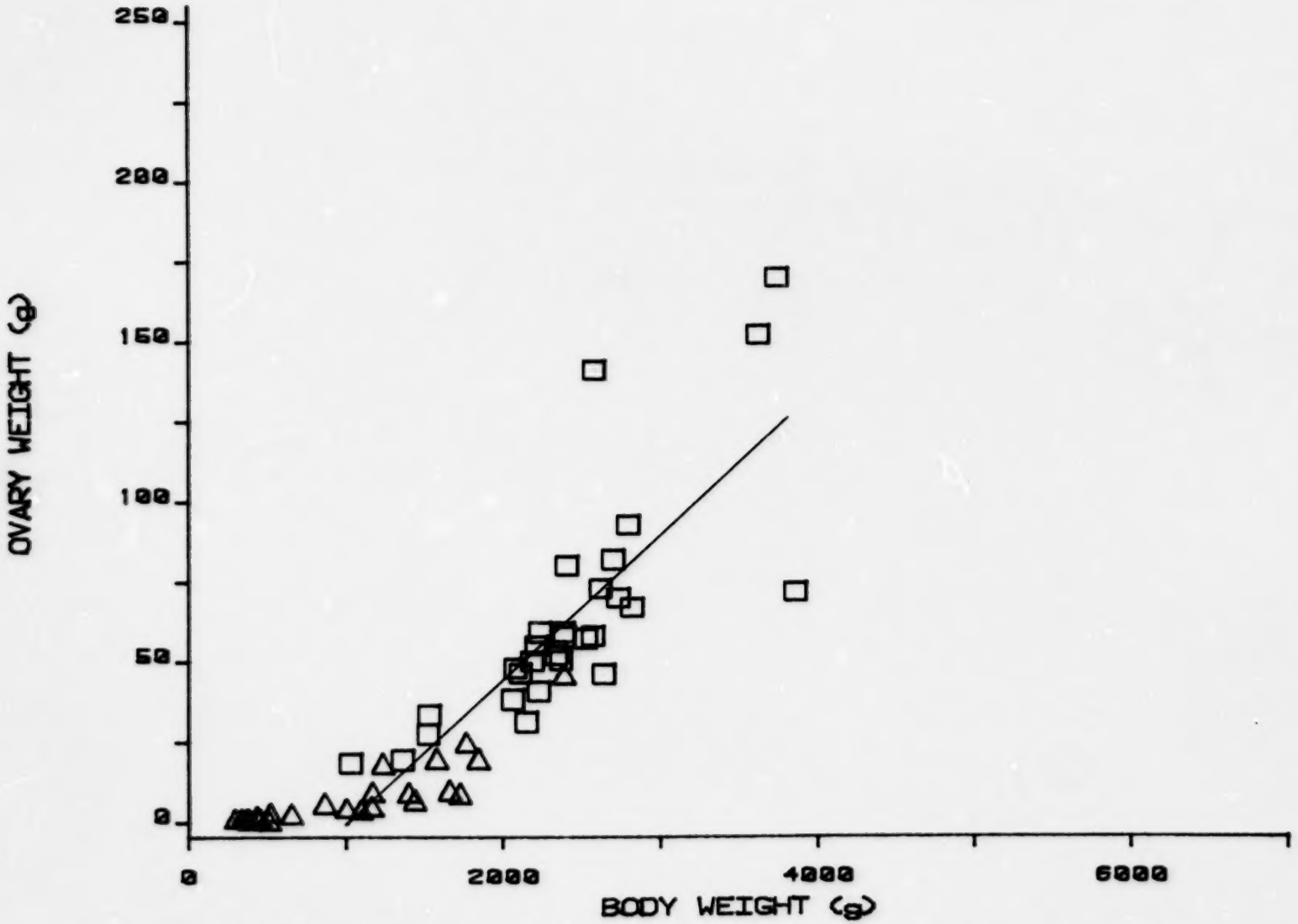


Fig. 11. Pacific cod ovary weight as a function of body weight for Horseshoe Ground. (Triangles = immature; squares = mature; solid line indicates linear regression on mature fish only: $Y=0.0448X-44.2$, $r^2 = 0.605$, $N = 29$.)

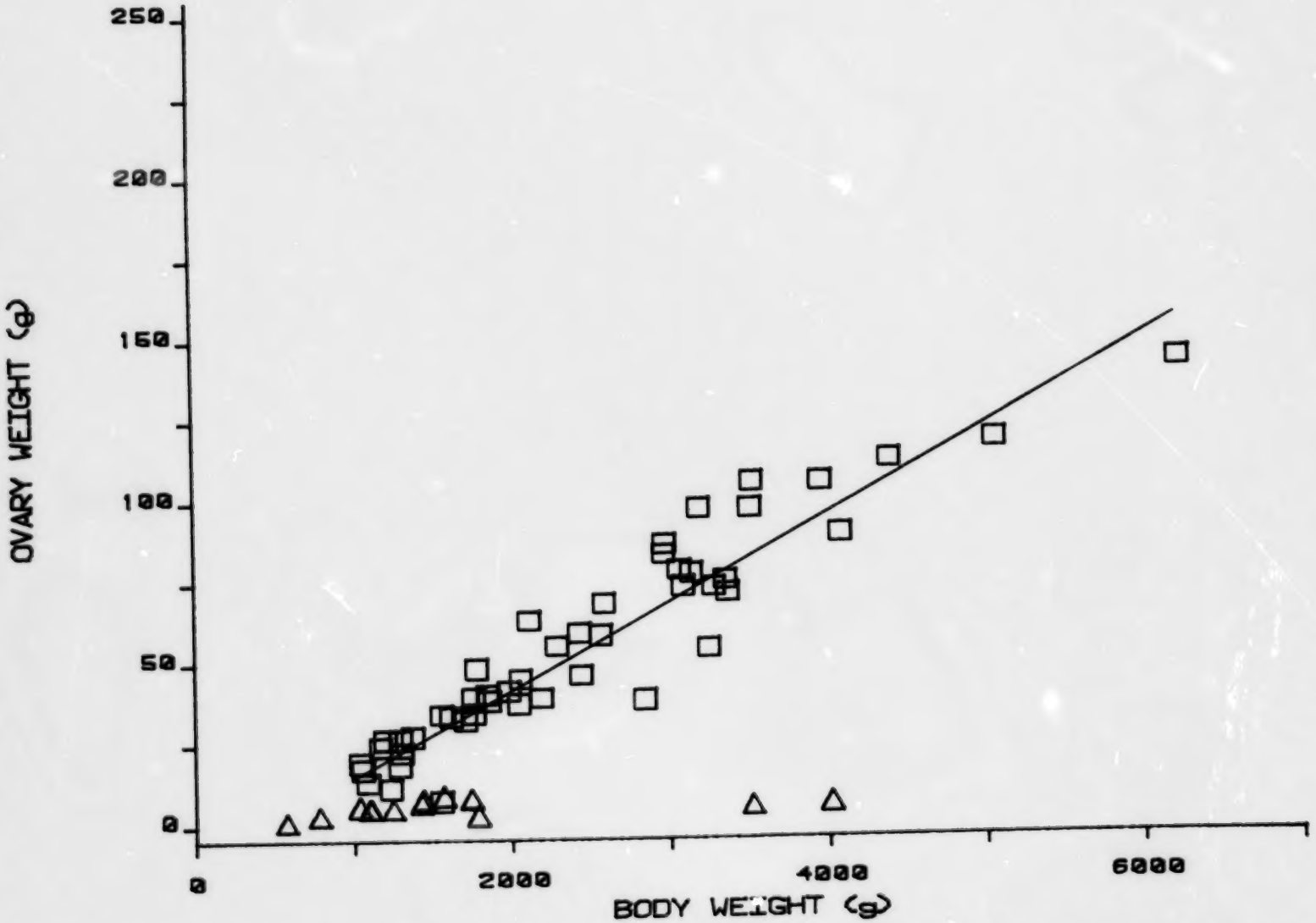


Fig. 12. Pacific cod ovary weight as a function of body weight for White Rocks/Bonilla Ground. (Triangles = immature; squares = mature; solid line indicates linear regression on mature fish only: $Y=0.0267X-10.6$; $r^2 = 0.893$; $N = 47$.)

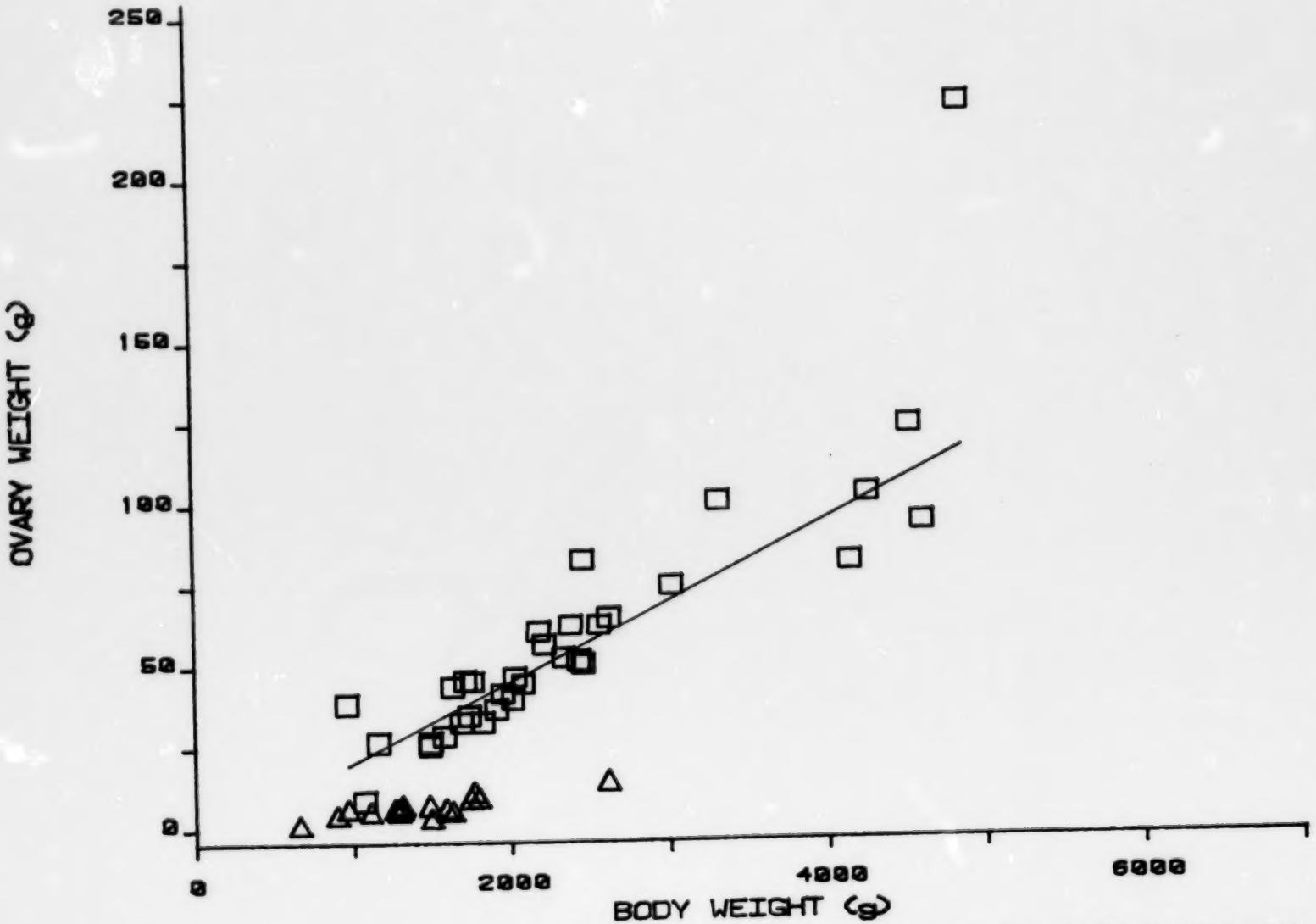


Fig. 13. Pacific cod ovary weight as a function of body weight for Two Peaks/Butterworth Ground. (Triangles = immature; squares = mature; solid line indicates linear regression on mature fish only: $Y=0.0249X-4.26$; $r^2 = 0.837$; $n = 32$, highest point not included.)

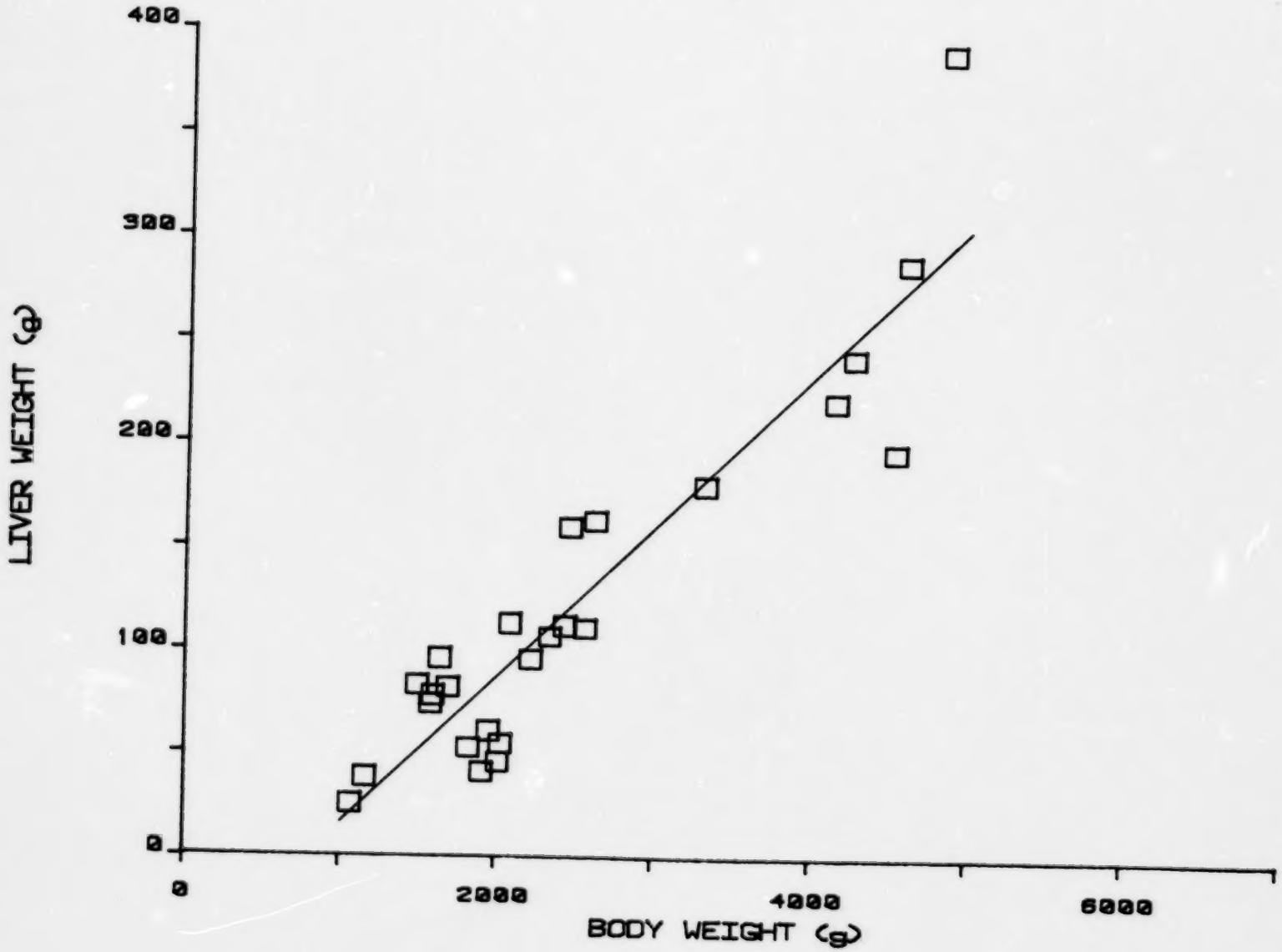


Fig. 14. Pacific cod liver weight as a function of body weight for Two Peaks/Butterworth Ground. (Squares = mature; solid line indicates linear regression: Y=0.0722X-55.9; r^2 = 0.853; n = 25.)

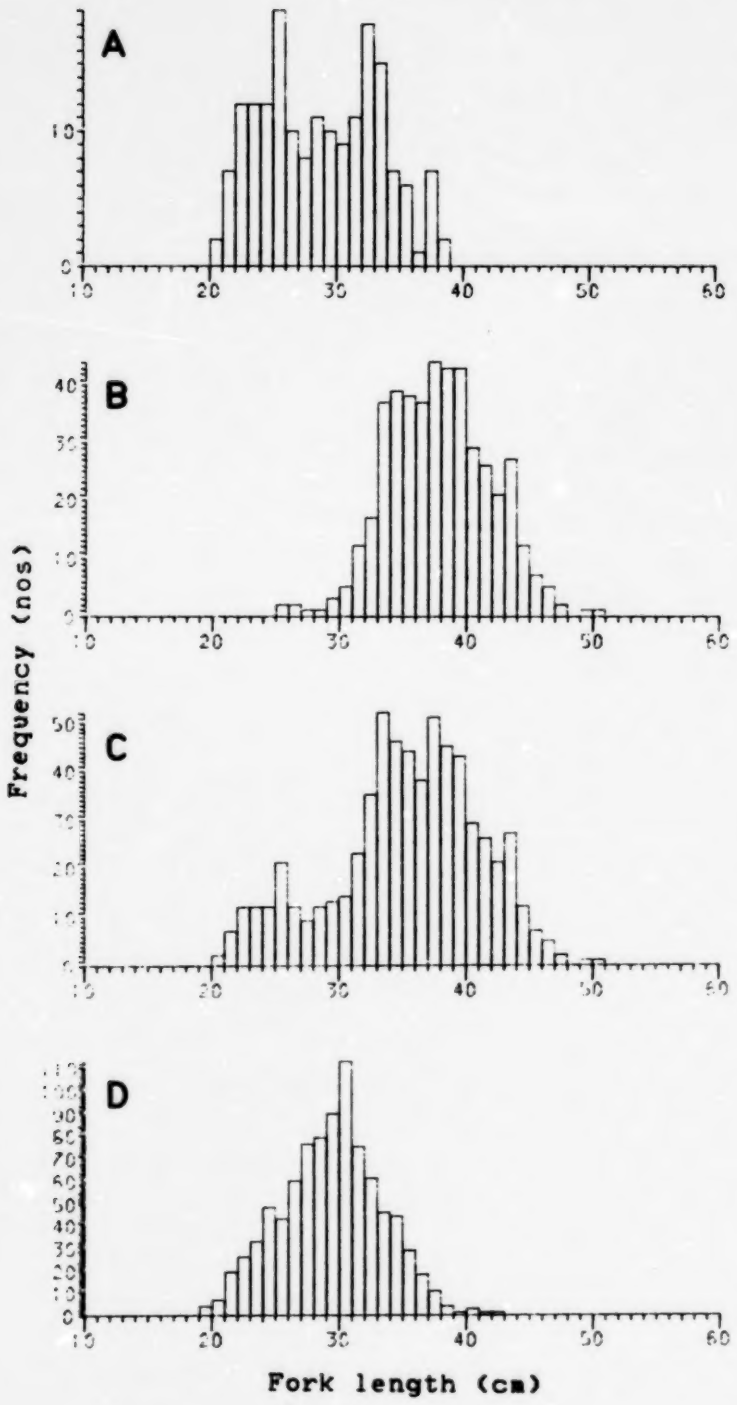


Fig. 15. Length frequency of English sole from Horseshoe Ground A) female immature, N=179; B) female mature, N=455; C) all females, N=755; D) males, N=892.

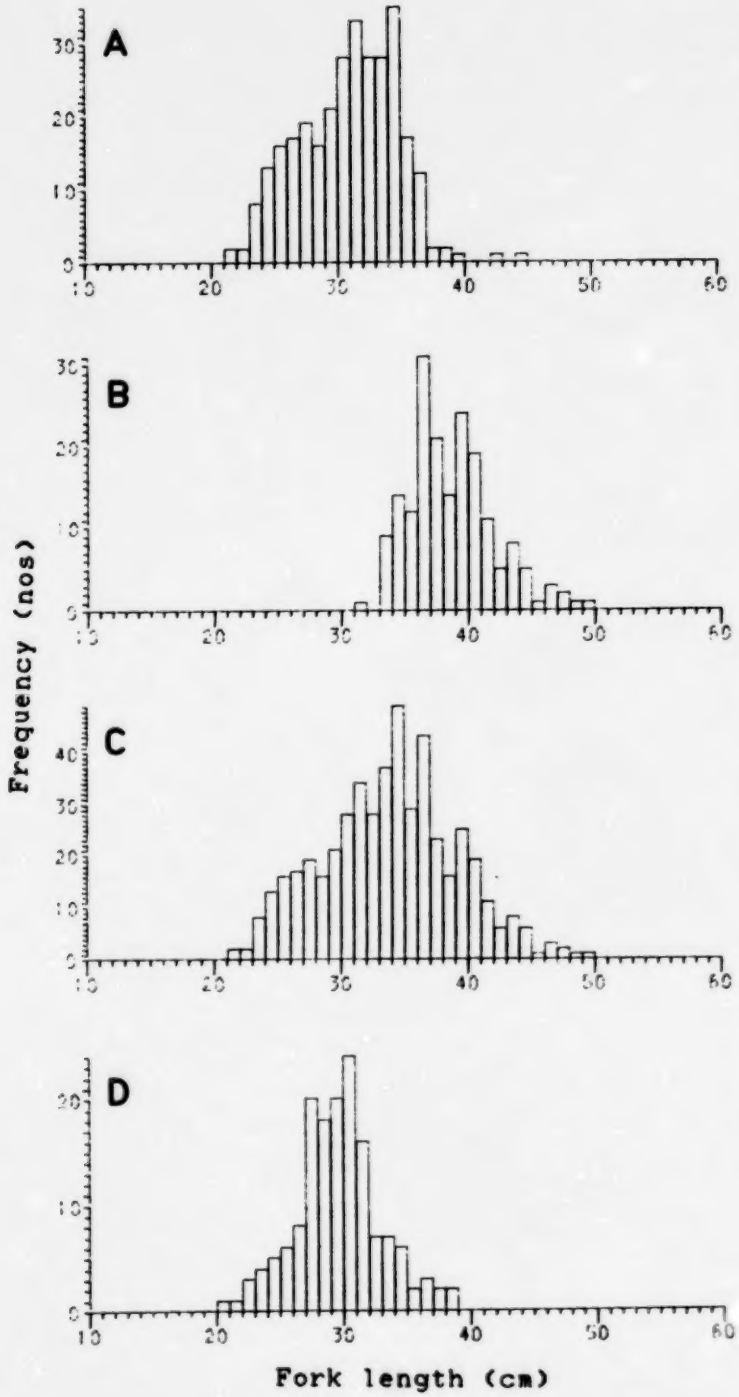


Fig. 16. Length frequency of English sole from Two Peaks-Butterworth Ground A) female immature, N=302; B) female mature, N=182; C) all females, N=484; D) males, N=155.

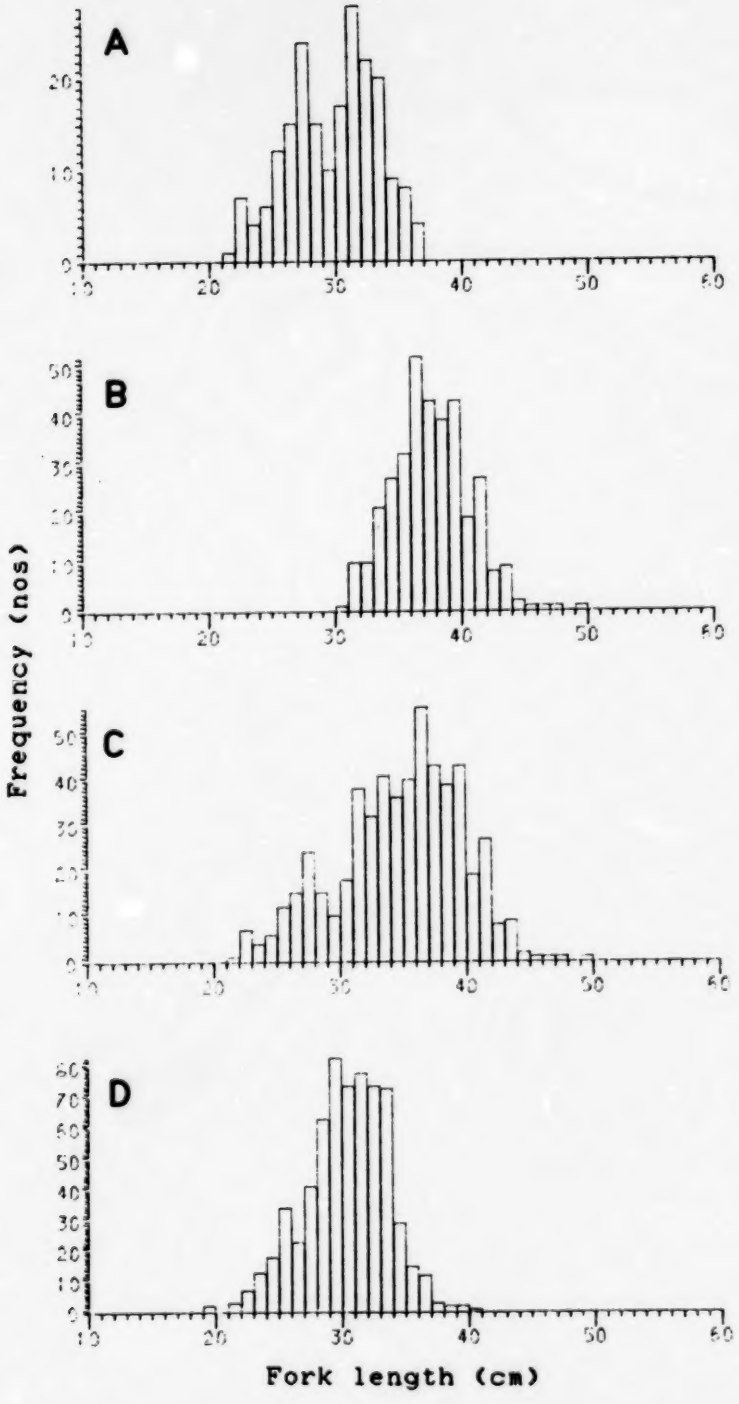


Fig. 17. Length frequency of English sole from White Rocks-Bonilla Ground A) female immature, N=202; B) female mature, N=347; C) all females, N=549; D) males, N=650.

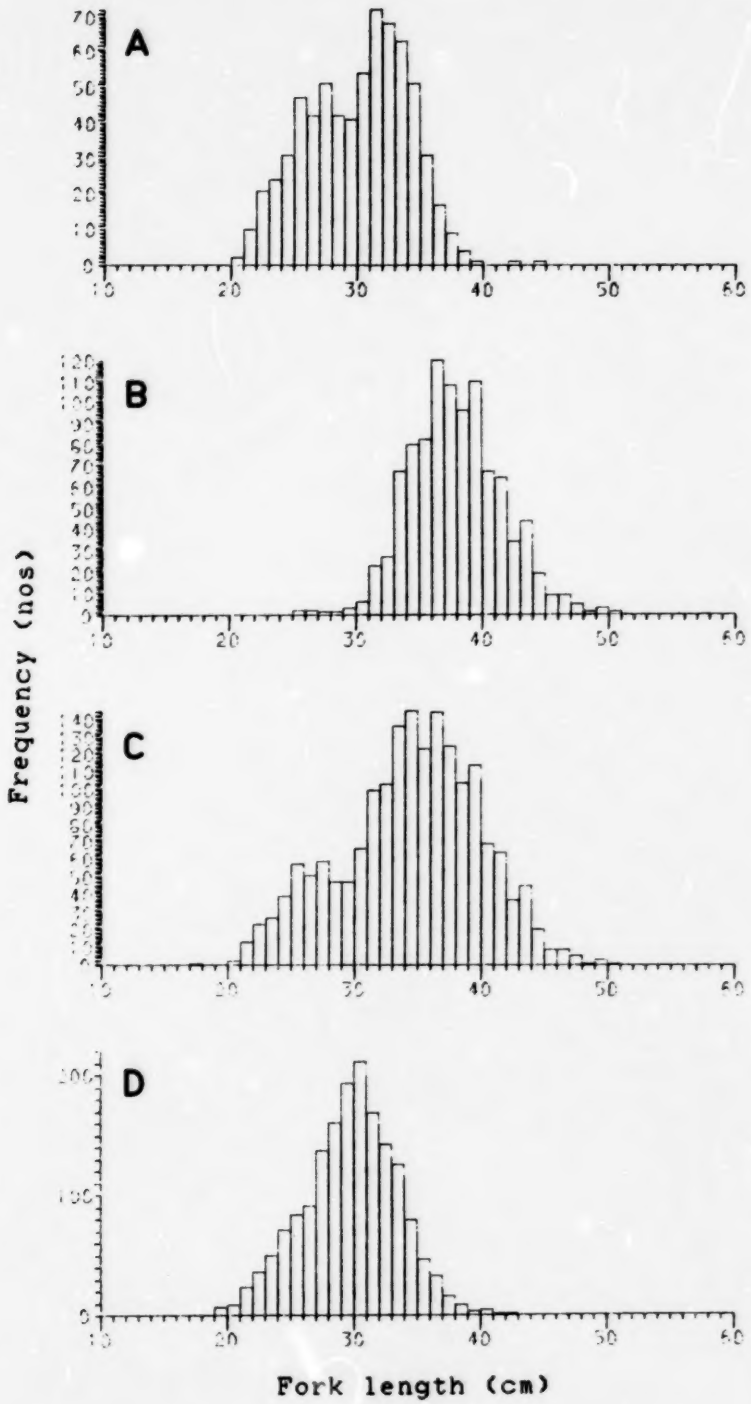


Fig. 18. Length frequency of English sole from all grounds combined A) female immature, N=683; B) female mature, N=984; C) all females, N=1788; D) males, N=1697.

Fig. 19. Percentage mature vs. length for English sole, all areas combined. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: Y=13.1X-384; r^2 = 0.980. Numbers sampled indicated.)

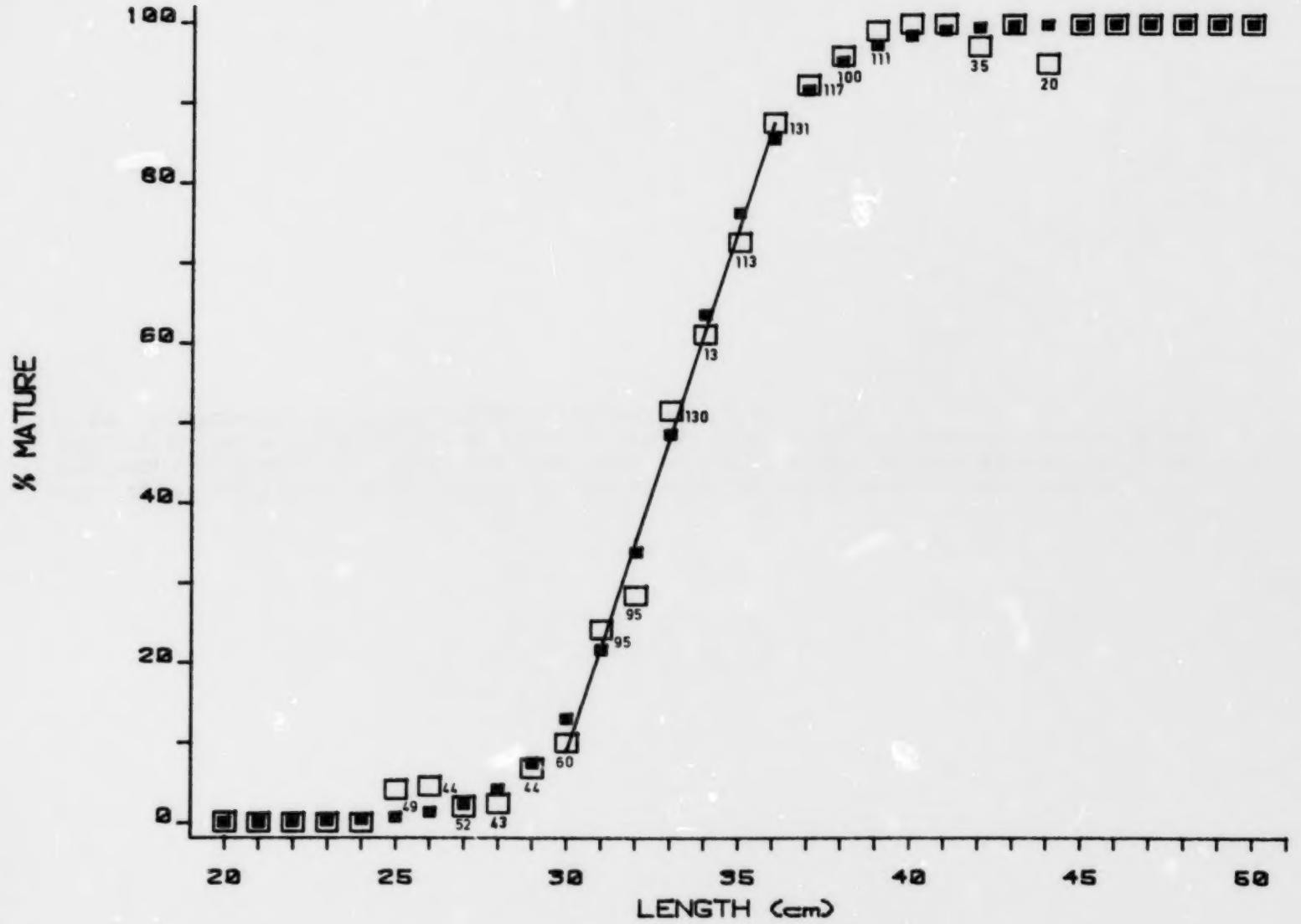

% MATURE
100
80
60
40
20
0
20
25
30
35
40
45
50
LENGTH (cm)
111
35
20
117
100
131
113
13
130
95
95
60
44
44
49
52
43

Fig. 20. Percentage mature vs. length for English sole, Horseshoe Ground. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=7.50X-183$; $r^2 = 0.884$. Numbers sampled indicated.)

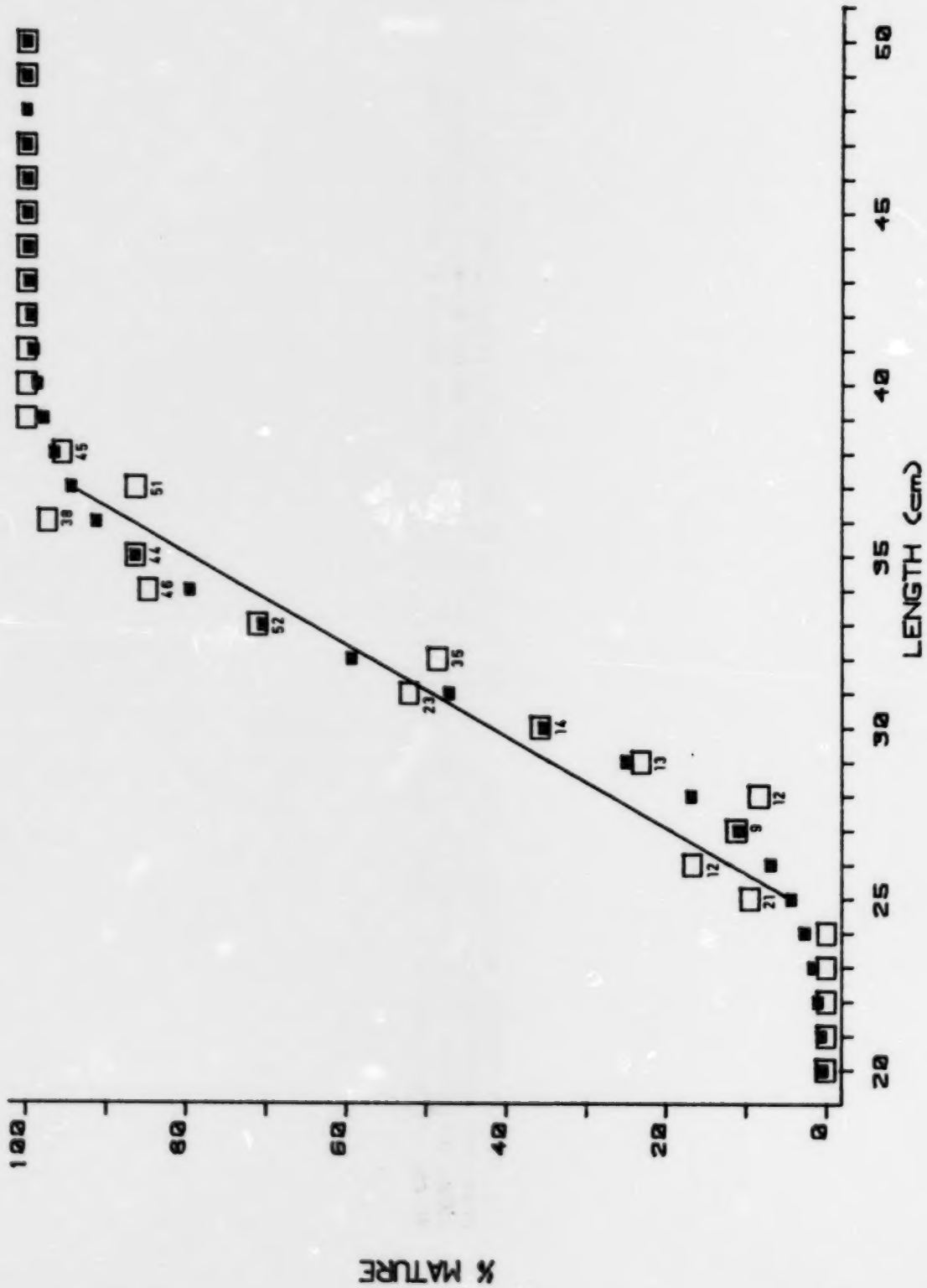

% MATURE
100
80
60
40
20
0
20
25
30
35
40
45
50
LENGTH (cm)
45
51
38
44
46
52
35
23
14
13
12
9
12
21

Fig. 21. Percentage mature vs. length for English sole, White Rocks/Bonilla. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=15.1X-449$; $r^2 = 0.865$. Numbers sampled indicated.)

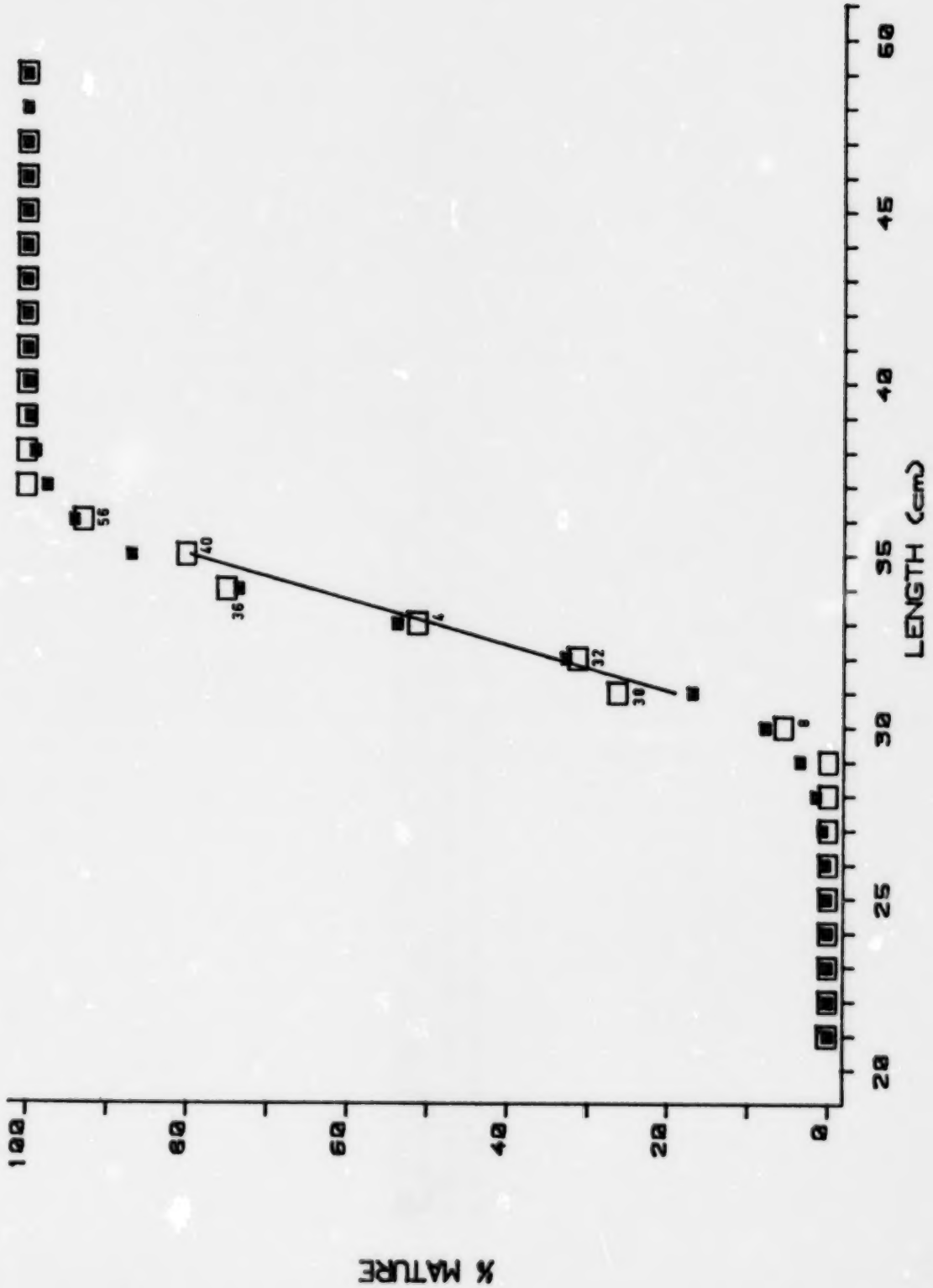

% MATURE
100
80
60
40
20
0
20
25
30
35
40
45
50
LENGTH (cm)
55
40
36
4
32
30
8

Fig. 22. Percentage mature vs. length for English sole, Two Peaks/Butterworth. (Open squares = observed; closed squares = values predicted using maximum likelihood method of Welch and Foucher 1988; solid line = linear regression including lengths at which percent mature is between 10 and 90 cm: $Y=7.88X-230$; $r^2 = 0.292$. Numbers sampled indicated.)

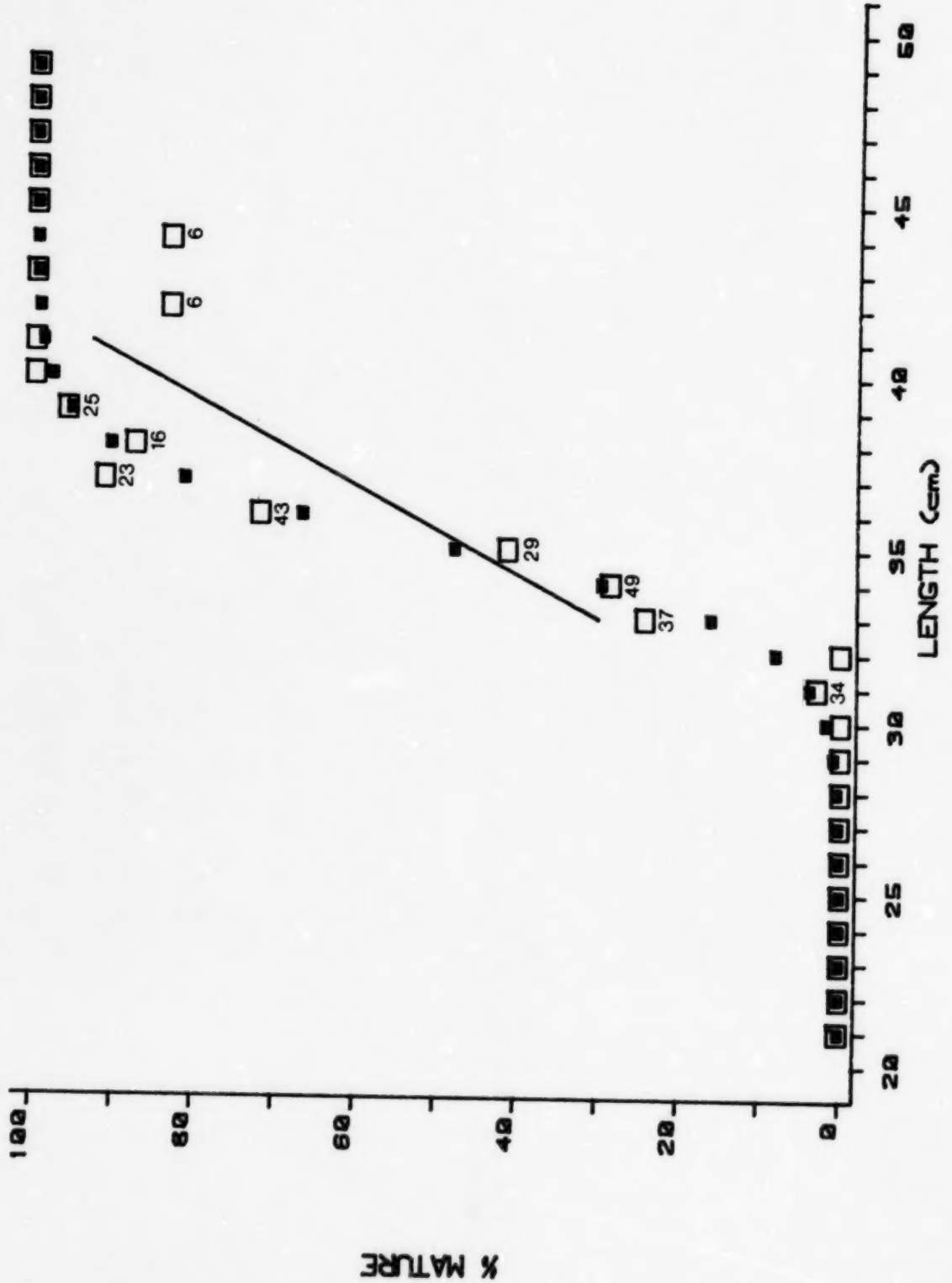

% MATURE
100
80
60
40
20
0
20
25
30
35
40
45
50
LENGTH (cm)
6
6
25
16
23
43
29
49
37
34

Fig. 23. English sole ovary weight as a function of body weight for Horseshoe Ground. (Squares = mature.)

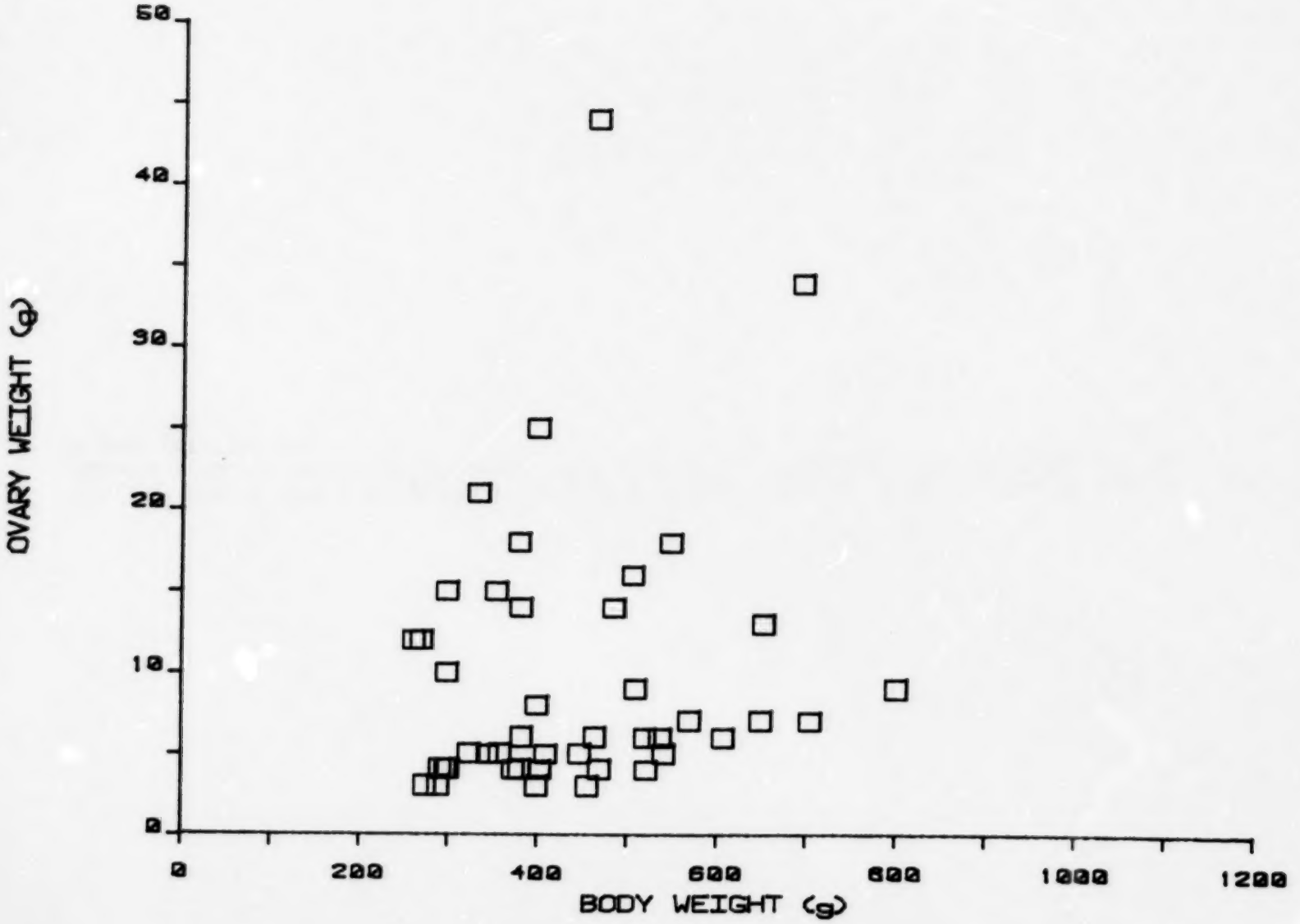

OVARY WEIGHT (g)
50
40
30
20
10
0
0
200
400
600
800
1000
1200
BODY WEIGHT (g)

Fig. 24. English sole ovary weight as a function of body weight for White Rocks/Bonilla Ground. (Squares = mature; solid line indicates linear regression: $Y=0.0158X-2.59$; $r^2 = 0.686$; $n = 38$, highest point omitted.)

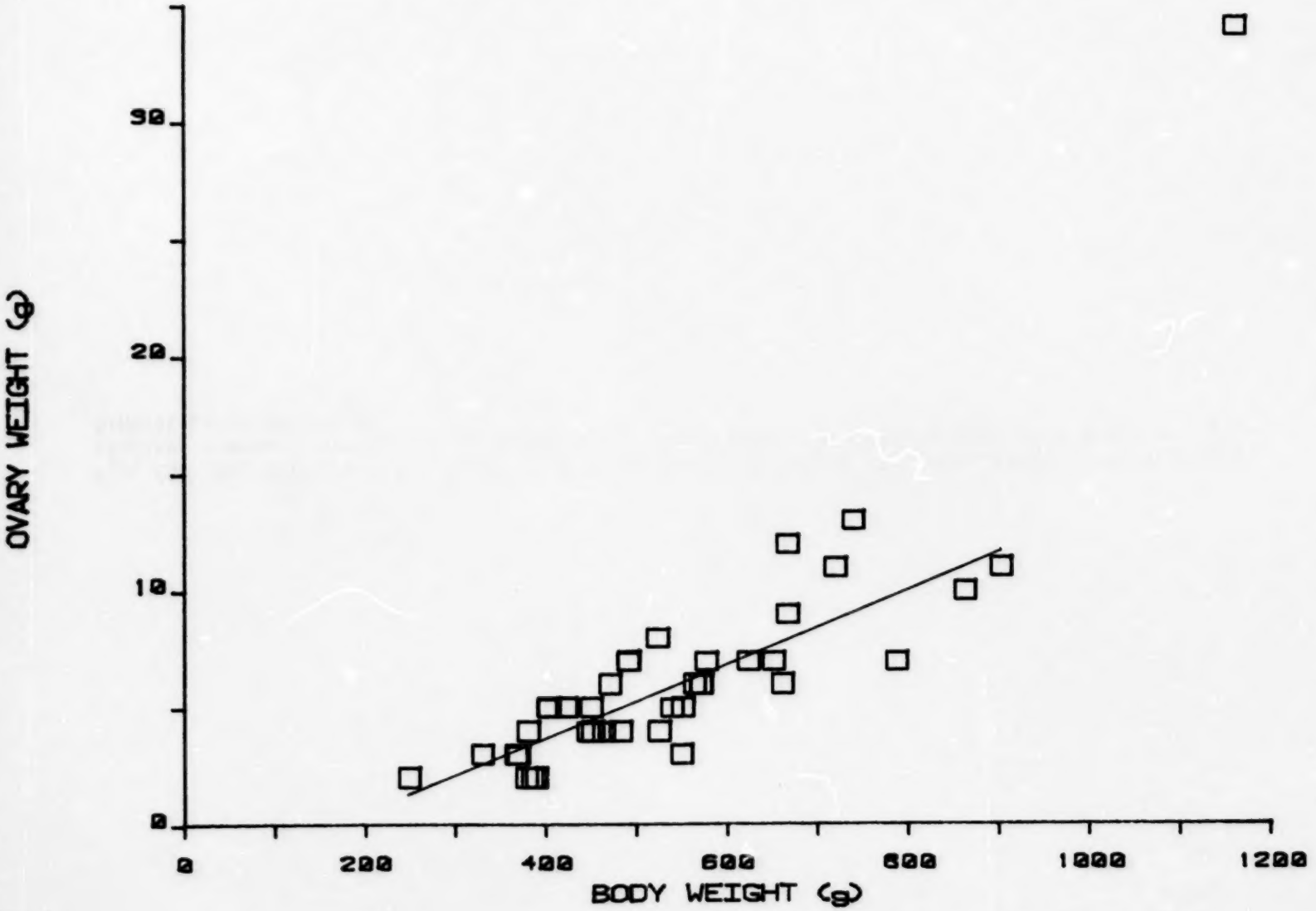

OVARY WEIGHT (g)
30
20
10
0
0
200
400
600
800
1000
1200
BODY WEIGHT (g)

Fig. 25. English sole ovary weight as a function of body weight for Two Peaks/Butterworth Ground. (Squares = mature; solid line indicates linear regression: $Y=0.00926X-0.818$; $r^2 = 0.333$; $n = 23$, highest point omitted.)

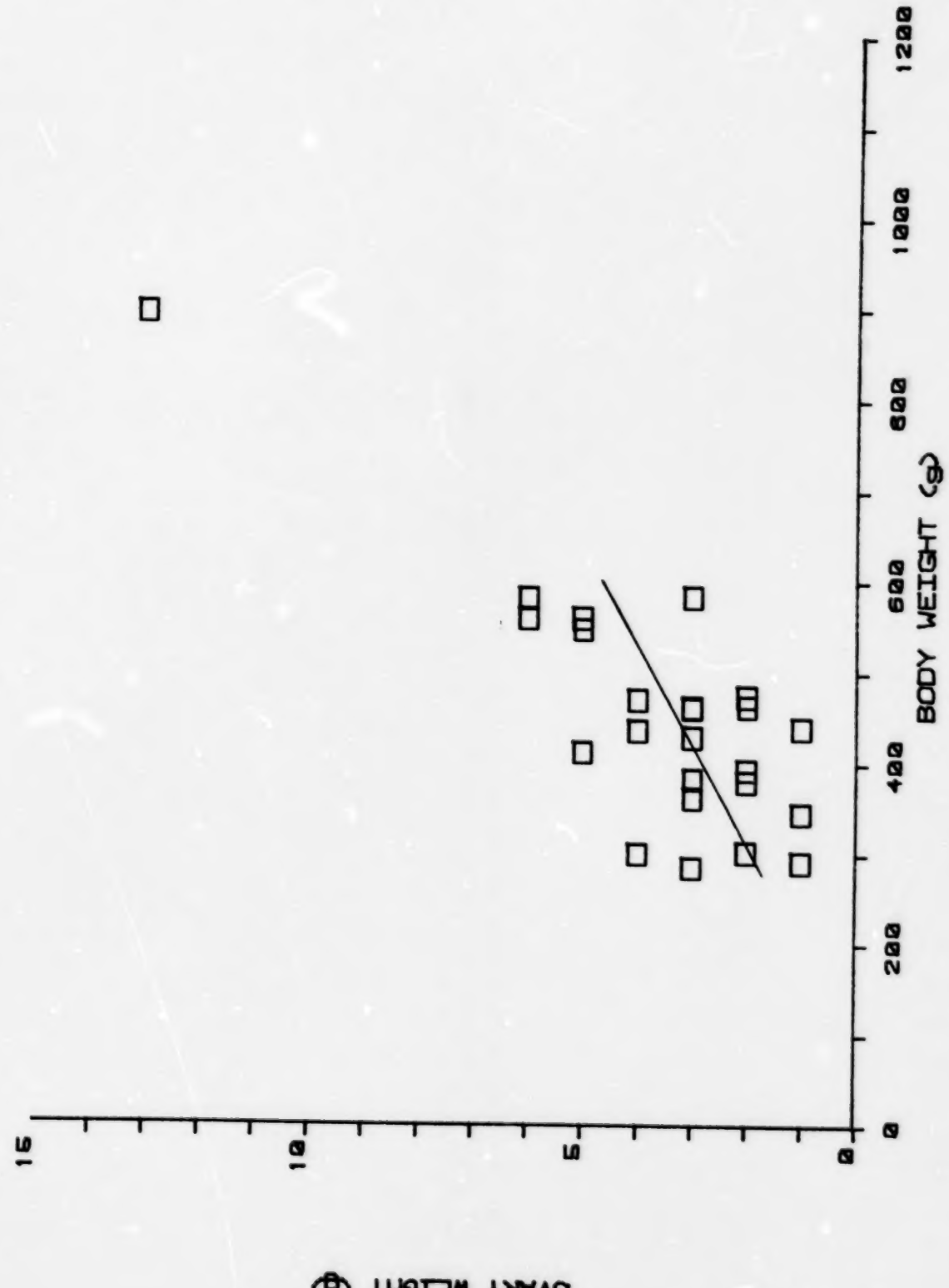
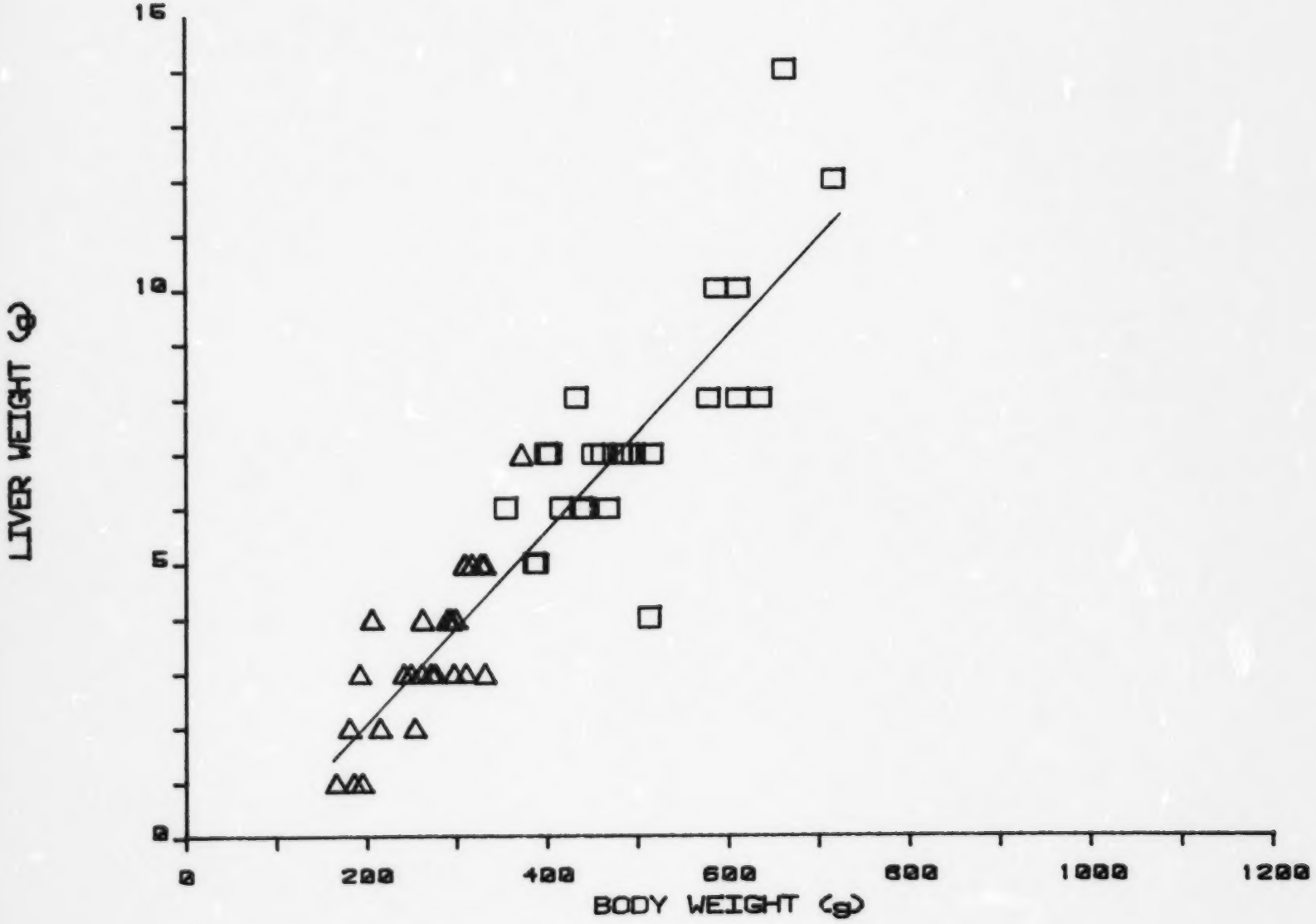

OVARY WEIGHT (g)
15
10
5
0
0
200
400
600
800
1000
1200
BODY WEIGHT (g)

Fig. 26. English sole liver weight as a function of body weight for White Rocks/Bonilla Ground. (Triangles = immature; squares = mature; solid line indicates linear regression for all fish: $Y=0.0178X-1.44$; $r^2 = 0.830$; $n = 50$.)


15
10
5
0
LIVER WEIGHT (g)
0
200
400
600
800
1000
1200
BODY WEIGHT (g)

Appendix Table 1. Bridge log for FRV W. E. RICKER cruise for studies on the reproductive biology of Pacific cod and English sole in Hecate Strait Nov. 2-13, 1987.

Haul number	1	2	3
Date	Nov. 4	Nov. 4	Nov. 4
Ground	Horseshoe	Horseshoe	Horseshoe
Start Time (PST)	0928	1056	1311
Duration (MIN)	30	30	30
Start N. Lat. (DEG)	53	52	53
(MIN)	00.2	59.9	01.0
W. Long. (DEG)	130	130	130
(MIN)	46.6	47.5	43.7
Start Loran-C X	12311.5	12306.1	12314.2
Z	41509.0	41505.7	41514.2
Finish N. Lat. (DEG)	52	52	52
(MIN)	59.4	59.2	59.9
W. Long. (DEG)	130	130	130
(MIN)	43.9	45.3	41.9
Finish Loran-C X	12324.0	12320.1	12329.2
Z	41508.4	41505.6	41512.4
Haul Distance (KM)	2.4	2.9	2.9
(N MI)	1.3	1.5	1.5
Direction (DEG. TRUE)	122	118	135
Depth-start (M)	97.8	87.8	1170
(FM)	53.5	48.0	64.0
Depth-finish (M)	99.9	92.1	121.0
(FM)	54.6	50.4	66.2
Catch (kg)			
Pacific cod	32	6	227
English sole	81	243	0

Appendix Table 1 (cont'd)

Haul number	4	5	6
Date	Nov. 5	Nov. 5	Nov. 5
Ground	Horseshoe	Horseshoe	Horseshoe
Start Time (PST)	0829	0954	1128
Duration (MIN)	30	30	30
Start N. Lat. (DEG)	53	53	52
(MIN)	00.9	00.9	59.9
W. Long. (DEG)	130	130	130
(MIN)	43.4	43.6	47.3
Start Loran-C X	12316.1	12314.5	12306.3
Z	41514.1	41514.2	41506.3
Finish N. Lat. (DEG)	52	52	52
(MIN)	59.9	60.0	59.3
W. Long. (DEG)	130	130	130
(MIN)	41.9	42.0	45.3
Finish Loran-C X	12329.2	12328.2	12319.0
Z	41512.2	41512.5	41506.1
Haul Distance (KM)	2.4	2.6	2.2
(N MI)	1.3	1.4	1.2
Direction (DEG. TRUE)	135	135	122
Depth-start (M)	115.0	115.0	89.9
(FM)	62.9	62.9	49.2
Depth-finish (M)	119.0	120.0	94.0
(FM)	65.1	65.6	51.4
Catch (kg)			
Pacific cod	109	120	1
English sole	48	31	76

Appendix Table 1 (cont'd)

Haul number	7	8	9
Date	Nov. 6	Nov. 6	Nov. 8
Ground	White Rocks	White Rocks	Two Peaks
Start Time (PST)	0903	1047	1338
Duration (MIN)	30	30	30
Start N. Lat. (DEG)	53	53	54
(MIN)	43.7	44.7	22.6
W. Long. (DEG)	130	130	131
(MIN)	46.8	45.1	14.7
Start Loran-C X	11982.8	11982.3	11562.0
Z	41660.6	41666.5	41744.9
Finish N. Lat. (DEG)	53	53	54
(MIN)	45.0	43.4	21.2
W. Long. (DEG)	130	130	131
(MIN)	48.5	44.4	14.9
Finish Loran-C X	11965.8	11995.5	11573.5
Z	41662.7	41662.9	41740.3
Haul Distance (KM)	3.2	2.6	2.2
(N MI)	1.7	1.4	1.2
Direction (DEG. TRUE)	324	163	184
Depth-start (M)	116.0	135.0	99.0
(FM)	63.4	73.8	54.1
Depth-finish (M)	112.0	134.0	97.0
(FM)	61.2	73.3	53.0
Catch (kg)			
Pacific cod	68	11	119
English sole	200	27	17

Appendix Table 1 (cont'd)

Haul number	10	11	12
Date	Nov. 10	Nov. 11	Nov. 11
Ground	Two Peaks	Butterworth	Butterworth
Start Time (PST)	1407	1014	1239
Duration (MIN)	30	28	30
Start N. Lat. (DEG)	54	54	54
(MIN)	22.7	04.8	04.9
W. Long. (DEG)	131	131	131
(MIN)	13.7	03.2	03.1
Start Loran-C X	11564.7	11750.5	11750.1
Z	41746.4	41706.2	41706.5
Finish N. Lat. (DEG)	54	54	54
(MIN)	21.2	03.4	03.4
W. Long. (DEG)	131	131	131
(MIN)	14.1	03.4	03.5
Finish Loran-C X	11575.9	11761.0	11759.9
Z	41741.5	41701.7	41701.7
Haul Distance (KM)	2.8	2.0	2.8
(N MI)	1.5	1.4	1.5
Direction (DEG. TRUE)	190	182	190
Depth-start (M)	86.0	87.1	88.0
(FM)	47.0	47.6	48.1
Depth-finish (M)	87.0	89.9	91.0
(FM)	47.6	49.2	49.8
Catch (kg)			
Pacific cod	58	94	42
English sole	100	70	30

Appendix Table 1 (cont'd)

Haul number	13
Date	Nov. 12
Ground	Bonilla
Start Time (PST)	0848
Duration (MIN)	30
Start N. Lat. (DEG)	53
(MIN)	290
W. Long. (DEG)	130
(MIN)	51.2
Start Loran-C X	12081.7
Z	41606.9
Finish N. Lat. (DEG)	53
(MIN)	27.8
W. Long. (DEG)	130
(MIN)	53.0
Finish Loran-C X	12080.3
Z	41597.8
Haul Distance (KM)	3.0
(N MI)	1.6
Direction (DEG. TRUE)	220
Depth-start (M)	102.0
(FM)	55.8
Depth-finish (M)	102.0
(FM)	55.8
Catch (kg)	
Pacific cod	2070
English sole	388

Appendix Table 2. Length frequency of Pacific cod sampled during the cruise of the FRV W.E. RICKER to Hecate Strait, November 2-13, 1987.

Fork length (cm)	Horseshoe			Two Peaks			White Rocks		
		Female			Female			Female	
	Male	Imm	Mat	Male	Imm	Mat	Male	Imm	Mat
19	-	3	-	-	-	-	-	-	-
20	1	1	-	-	-	-	-	-	-
21	10	4	-	-	-	-	-	-	-
22	19	12	-	-	-	-	-	-	-
23	7	9	-	-	-	-	-	-	-
24	4	3	-	-	-	-	-	-	-
25	0	1	-	-	-	-	-	-	-
26	0	0	-	-	-	-	-	-	-
27	0	0	-	-	-	-	-	-	-
28	0	0	-	-	-	-	-	-	-
29	0	0	-	-	-	-	-	-	-
30	1	0	-	-	-	-	-	-	-
31	0	1	-	-	-	-	-	-	-
32	1	2	-	-	-	-	-	-	-
33	4	0	-	-	-	-	-	-	-
34	4	2	-	-	-	-	-	-	-
35	3	3	-	-	-	-	-	-	-
36	2	0	-	-	-	-	-	-	-
37	2	1	-	-	-	-	-	-	-
38	1	2	-	-	1	-	-	-	-
39	4	0	-	-	1	-	2	1	-
40	3	0	-	-	0	-	1	3	-
41	2	1	-	1	1	-	3	6	1
42	4	2	-	1	0	-	5	2	0
43	1	0	1	2	0	-	6	1	2
44	3	1	0	3	0	-	13	2	2
45	1	2	1	4	2	-	10	3	2
46	6	1	0	2	2	2	17	6	3
47	2	2	2	3	3	0	19	3	9
48	6	5	3	3	3	0	21	12	14
49	8	1	4	5	6	0	23	7	14
50	2	1	3	2	6	3	20	8	16
51	6	1	3	8	3	3	26	13	19
52	6	1	4	11	3	0	28	9	22
53	4	1	5	5	8	3	32	10	29
54	7	1	4	7	7	0	30	4	33

Appendix Table 2 (cont'd)

Fork length (cm)	Horseshoe			Two Peaks			White Rocks		
		Female			Female			Female	
	Male	Imm	Mat	Male	Imm	Mat	Male	Imm	Mat
55	5	2	7	5	1	1	28	1	32
56	9	0	7	2	1	4	35	6	34
57	5	1	6	3	0	1	31	0	23
58	2	-	11	4	0	5	38	0	31
59	5	-	5	4	0	2	43	0	33
60	4	-	5	2	0	0	23	0	38
61	2	-	8	1	0	0	18	0	28
62	3	-	3	2	1	2	13	0	21
63	4	-	6	1	-	0	8	0	20
64	4	-	3	1	-	1	7	0	10
65	1	-	2	1	-	0	3	0	10
66	0	-	1	0	-	1	2	0	4
67	2	-	1	0	-	0	2	0	4
68	0	-	0	1	-	0	1	1	2
69	2	-	3	0	-	2	2	1	0
70	0	-	0	0	-	1	1	-	0
71	0	-	0	0	-	2	2	-	1
72	1	-	0	1	-	-	1	-	1
73	0	-	0	0	-	-	-	-	3
74	0	-	1	0	-	-	-	-	1
75	0	-	0	1	-	-	-	-	0
76	0	-	0	-	-	-	-	-	0
77	1	-	0	-	-	-	-	-	1
78	-	-	0	-	-	-	-	-	-
79	-	-	0	-	-	-	-	-	-
80	-	-	0	-	-	-	-	-	-
81	-	-	0	-	-	-	-	-	-
82	-	-	0	-	-	-	-	-	-
83	-	-	1	-	-	-	-	-	-
Total	174	67	100	86	49	33	514	99	463

Appendix Table 3. Length frequency of English sole sampled during the cruise of the FRV W.E. RICKER to Hecate Strait, November 2-13, 1987.

Fork length (cm)	Horseshoe				Two Peaks			White Rocks		
		Female				Female			Female	
	Male	Imm	Mat	I/M[a]	Male	Imm	Mat	Male	Imm	Mat
17	-	-	-	1	-	-	-	-	-	-
18	-	-	-	0	-	-	-	-	-	-
19	4	-	-	0	-	-	-	2	-	-
20	7	2	-	0	1	-	-	0	-	-
21	19	7	-	3	1	2	-	3	1	-
22	26	12	-	2	3	2	-	7	7	-
23	33	12	-	3	4	8	-	13	4	-
24	48	12	-	8	5	13	-	18	6	-
25	43	19	2	8	6	16	-	34	12	-
26	60	10	2	7	8	17	-	23	15	-
27	76	8	1	7	20	19	-	41	24	-
28	79	11	1	4	18	16	-	63	15	-
29	90	10	3	3	20	21	-	83	10	-
30	113	9	5	6	24	28	-	74	17	1
31	75	11	12	4	16	33	1	78	28	10
32	61	18	17	8	7	28	0	74	22	10
33	46	15	37	6	7	28	9	73	20	21
34	44	7	39	14	6	35	14	29	9	27
35	29	6	38	10	2	17	12	15	8	32
36	18	1	37	7	3	12	31	12	4	52
37	11	7	44	8	2	2	21	3	-	43
38	4	2	43	4	2	2	14	2	-	39
39	1	-	43	3	-	1	24	2	-	43
40	3	-	29	2	-	0	19	1	-	19
41	1	-	26	0	-	0	11	-	-	27
42	1	-	21	2	-	1	5	-	-	8
43	-	-	27	1	-	0	8	-	-	9
44	-	-	12	-	-	1	5	-	-	2
45	-	-	7	-	-	-	1	-	-	1
46	-	-	5	-	-	-	3	-	-	1
47	-	-	2	-	-	-	2	-	-	1
48	-	-	0	-	-	-	1	-	-	0
49	-	-	1	-	-	-	1	-	-	1
50	-	-	1	-	-	-	-	-	-	-
Total	892	179	455	121	155	302	182	650	202	347

[a]I/M = maturity not recorded.